CHAPTER 4
SAMPLING STRATEGIES

This chapter discusses sampling strategies for the focused and expanded SI and provide guidelines for developing sample plans. The chapter also discusses the conditions and objectives for the single SI approach. Special guidance on sampling strategies for sites containing radioactive substances is provided at the end of the chapter. The investigator should tailor sampling strategies to collect samples to demonstrate the presence of hazardous substances and determine whether those substances have migrated from sources or disposal locations. SI objectives and sampling strategies, however, may change as site-specific factors change or become known.

Because uncontrolled hazardous waste sites vary greatly in size and complexity, specific SI sampling guidelines that apply to all sites are not possible. The primary purpose of the Sl sampling program is to assess the nature of the problem at the site, and to support response and further action decisions. Additional purposes include meeting public information needs and incorporating remedial investigation (RI) sampling objectives whenever possible. SI sampling is not meant to determine the full extent of a hazardous substance problem at a site, nor is it limited to the data needed to score the site according to the HRS.

Sample locations should be selected based on the likelihood of detecting hazardous substances at higher than background level concentrations. After reviewing available information, the investigator should prepare the SI sample plan, including the location, number, and types of samples to be collected. Table 4-1 presents sample planning considerations.

The investigator should also determine the parameters for sample analysis. If previous analytical results do not adequately assess all the potential hazardous substances, full target analyte list (TAL) or target compound list (TCL) analysis should be performed. However, full TAL or TCL analysis may not be required for SIs where previous analytical results address specific analytes or classes of substances (e.g., pesticides, volatile organic compounds). Partial analyses should be considered during planning because they are less expensive or may have lower quantitation limits than full TAL or TCL analysis.

Section 3.1.1 provides more information on sample types (e.g., media, waste, grab, field screening). Also, EPA's *A Compendium of Superfund Field Operations Methods* (OSWER Directive 9355.0-14) contains detailed information on sampling procedures and techniques.

4.1 SI SAMPLING PRINCIPLES

The following key principles can be the basis of an effective sample plan. Note that site-specific circumstances, including adverse weather, sampling equipment problems, sample location accessibility, health and safety concerns, and CLP scheduling may affect the application of these principles.

4.1.1 General Sampling Principles

Sample to Identify Targets Exposed to a Hazardous Substance: Identifying populations or sensitive environments exposed to hazardous substances is a critical early step in protecting public health and the environment under the Superfund program. The presence of contamination at a target contributes significantly to the HRS score and triggers a high priority for follow up action. Absence of target contamination is also important because it could indicate that public health is not endangered or that no further investigation is necessary. Sampling targets (e.g., drinking water wells and intakes, sensitive environments, fisheries) within target distance limits can accomplish two objectives during the SI:

- It may demonstrate a release.

TABLE 4-1: SAMPLE PLANNING CONSIDERATIONS

CRITERION	CONSIDERATIONS
Sources	Source types Safety Containment Available data
Number of pathways sampled	Pathway media Strata within HRS pathway media Targets likely to be exposed to contamination Probability of release to media Probability of contamination attributable to the site
Number of QC samples	Screening vs. listing Field duplicate, replicate, split Number of samples Blank (trip, field, equipment rinsate) Field evaluation
Number of background and attribution samples	Screening vs. listing Number of source samples Alternative sources of contamination
Application (usability) of previous samples	Analytical results Quality Reliability Sample dates, locations, and descriptions Potential for data validation
Analytical methods	Previous analytical data Costs Detection Limits

- A measurable concentration of a hazardous substance found at the target may be used to evaluate target exposure relative to media-specific benchmarks.

Analytical support to detect substances at or above benchmarks, particularly in drinking water samples, may require planning for special CLP analyses.

As a general rule, sample locations should be selected for targets that may be contaminated by hazardous substances likely to be attributable to the site. Sampling should focus on migration paths and the direction of nearest targets. The SI investigator should evaluate the likelihood of finding measurable concentrations at various distances from site sources.

Sample to Identify Hazardous Substances Present at the Site: The objective of sampling sources is to identify hazardous substances present and to support attributing them to the site. Source samples may not be necessary if previous data document the types of waste found at the site. However, if data are not available or reliable, sources and other possible wastedisposal locations may need to be sampled.

If multiple hazardous substances are suspected at the site, sampling should focus on the more mobile substances, which are generally easier to locate in a specific medium, particularly soil, because of their greater tendency to migrate. Most hazardous substances will segregate into one or more media based on their physical and chemical characteristics-

for example, PCBs tend to bind to soils and may not be present in all pathways.

Sample to Demonstrate a Release: SI sampling should focus on demonstrating the release of a hazardous substance to a pathway, particularly when a release is either suspected during the PA and contributes significantly to the site score or was not fully documented previously.

To demonstrate a release, analytical data must:

- Indicate that the hazardous substance is present at levels significantly above background.
- Demonstrate that the significant increase is at least partially attributable to the site.

For the soil exposure pathway, the investigator must collect soil samples to support the presence of observed contamination in surficial materials.

Suspected releases that are not critical to the site screening or listing decision should not be sampled. An SI sampling approach should consider evaluating the non-critical pathway for potential to release and allocating samples for the factors critical to the site score.

Sample to Discriminate Among Alternative Sources of Contamination: If there are multiple sources of contamination in the area of the site being investigated, sampling should be designed to determine whether the site is at least partially responsible for the contamination (see Section 4.5.3).

Sample to Determine Representative Background Concentrations: To determine whether a hazardous substance is present significantly above background, the background level must be known. The investigator should consider whether the concentrations of hazardous substances are related to naturally occurring levels or offsite influences. Background samples are normally collected during the SI. However, in some situations they may not be required-for example, when the substance does not occur naturally and is known to be present at the site based on previous analytical data. The same methods should be used whenever possible to sample and analyze both background and elevated concentrations.

Sample to Verify Field and Laboratory Practices: QA/QC samples help to monitor any contamination introduced by field methods, evaluate laboratory analytical results, and help increase overall confidence in analytical results. QA (or performance) samples relate to procedures regarding program oversight, while QC samples relate to the methods themselves. During the SI, these samples should be collected using the same methods as for other samples-for example, the QC samples should be stored, transported, and analyzed in the same manner as site samples. Several types of QC samples may be collected, including split and duplicate samples, as well as field and trip blanks (see Section 3.3).

4.1.2 Focused Sl Sampling Principles

The focused SI emphasizes collecting analytical data to test site hypotheses generated during the PA and to determine the need for further investigation. During the focused SI, the investigator collects samples to determine the types of hazardous substances at the site, whether a hazardous substance has been released, and whether the release impacts targets.

During the focused SI, sampling should test hypotheses for the ground water and surface water pathways where a release suspected during the PA contributed significantly to the further action decision. Also, sampling may be warranted to test the presence of actual contamination for the soil exposure pathway. For sites with a suspected release and primary target hypotheses, sampling to demonstrate actual target contamination also tests the suspected release hypothesis.

Sample results will be the most important factor in determining whether or not a site will require further investigation after the focused SI. Making effective screening decisions with a limited number of samples depends on carefully planning the focused SI sampling strategy. Principles emphasized during the focused SI sampling include:

- Identifying targets exposed to a hazardous substance;
- Identifying hazardous substances present at a site; and
- Demonstrating a release.

Other factors that may affect the sampling approach depend on the objectives of the investigation, number of site hypotheses to be tested, availability and quality of previous analytical results, and site characteristics. To illustrate the focused SI sampling strategy, consider the example in the sidebar.

Other considerations of focused SI sampling strategies include the following.

- **Concentrate samples on major pathways affecting the score:** For most sites, only certain pathways will be of concern after the PA. The importance of a specific pathway and the individual factor scores for a site must be taken into account when developing the focused SI sample plan. Sample collection should emphasize evaluating factors most critical to the site score.

- **Use previous analytical data:** If any previous data are usable for the focused SI (see criteria discussed in Section 3.2), they should be used to evaluate the site and facilitate planning sample locations. For example, if reliable previous data demonstrate site-related contamination in an area, do not resample these areas during the focused SI. Note that if previous analytical data indicate an HRS score of 28.50 or greater, the site may be a candidate for the single SI rather than a focused SI.

- **Limit collection of background and QA/QC samples:** Demonstrating a release or an actually contaminated target for screening purposes does not require the full complement of background and QA/QC samples needed for an expanded SI. Conserve field investigation hours and sampling costs by limiting the number of background and QA/QC samples, where appropriate.

Table 4-2 summarizes sampling criteria and considerations to help the investigator plan samples to meet focused SI objectives.

4.1.3 Expanded and Single SI Sampling Principles

All sampling principles are emphasized during the expanded and single Sl; however, some principles may apply to a lesser extent depending on availability and

EXAMPLE OF FOCUSED SI SAMPLING STRATEGY

A site advanced to the focused SI based solely on suspected contamination of nearby surface water used for recreational fishing. The SI investigator proposed to sample along the overland migration path towards surface water. However, those samples would not directly test the PA hypothesis that the fishery is exposed to contamination. Theoretically, a single sediment sample taken at a likely area of sediment accumulation in surface water near the probable point of entry (PPE) can test two hypotheses—suspected contamination of a fishery and suspected release to surface water. A second sediment sample collected at the PPE would increase the probability of detecting contamination, increase confidence in the sample results, and may address quality control of sampling procedures. If a hazardous substance is not detected in the PPE sample, the site may receive a SEA recommendation. The investigator may consider collecting several sediment samples from the PPE since testing the hypothesis of an actually contaminated fishery is critical to the screening decision.

and quality of information (including previous analytical results) to support HRS documentation requirements. For most sites, not all pathways will prove to be of concern after the focused SI. The relative importance of the pathway for the site must be taken into account when planning expanded SI samples.

The primary objectives of the expanded SI are to collect fully documented data to prepare an HRS package and, for some sites, to collect field data for the remedial investigation (RI). Expanded SI sampling should be designed to completely investigate and document observed releases, observed contamination, and levels of target exposure to contamination. The focused and expanded SI may require different degrees of documentation for key HRS factors. For example, if the focused SI indicates that surface water sediments have high concentrations

TABLE 4.2: PRIORITIES FOR FOCUSED SI SAMPLES

SAMPLE BUDGET CATEGORY	PRIORITIES
Number of pathways to evaluate with samples	Sample Pathways critical to PA further action recommendation If multiple pathways are critical to screening decision, plan sampling to test all critical hypotheses
Number of targets sampled	Sample primary drinking water wells and intakes suspected of exposure to site-related contamination (see glossary: Primary Target) Sample nearest targets or targets most likely to be exposed to site-related contamination for critical pathways if contamination suspected during PA If sample budget permits, take more than one sample at surface water and soil target locations that are critical to the site decision
Number of sources sampled	Sample sources to identify hazardous substances present at site If multiple sources exist, sample each different source type
Number or release samples	Sample to test if a release has occurred for critical pathways. When possible, test release hypotheses in conjunction with target samples If the magnitude of potentially contaminated targets is responsible for screening decision, limit number of release samples
Number of background and QA/QC samples	Limit collection of background and QA/QC samples to those needed to screen site. Background or QA/QC samples may not be necessary
Other criteria	Use previous analytical data to plan sample locations Do not resample at locations where reliable previous analytical data detected a hazardous substance

of metals, the expanded SI would include collecting samples to establish sediment background concentrations to attribute the metals to the site being evaluated, and samples to document surface water targets exposed to actual contamination.

The expanded SI also involves field activities to document aspects of the HRS evaluation that may be beyond the scope of a focused SI which is limited to screening. If necessary, the following may be expanded SI activities:

- Install monitoring wells.
- Collect physical parameter data of subsurface.
- Install boreholes.
- Collect non-routine soil gas or air samples.
- conduct geophysical surveys to delineate areas of buried waste.
- Document waste characteristics for significant sources (e.g., hazardous waste quantity).
- Supplement documentation of releases and areas or contamination (e.g., fisheries, soils).
- Supplement documentation of targets exposed to actual contamination.
- Distinguish the level of contamination (e.g., Level I) for targets.
- Document complex attribution issues (e.g., industrial areas and ground water plumes).
- Support the quality of analytical data with additional QA/QC samples.

EXAMPLE OF EXPANDED SI SAMPLING STRATEGY

A site advanced to the expanded SI based on observed contamination on school property and a suspected release to ground water. For the school property, surficial soil samples detected hazardous substances, but concentrations were not quite above health-based benchmarks. In addition, background soil sample analytical results were qualified (code as "UJ") during data validation due to low recovery of internal standards. The data reviewer commented that these results were biased low, resulting in reported concentrations most likely below real concentrations. The investigator did not feel confident that these samples fully investigated contamination on the school property, and decided to resample during the expanded SI to document the threat to resident population targets for the soil exposure pathway, including the level of contamination for the student population.

For this site, the only background groundwater sample collected during the focused SI was 2 miles from the site, and other sources of contamination were nearby. Drinking water wells were not likely to be exposed to actual contamination, while the school and several residential properties were likely to be exposed. The investigator determined that the soil exposure pathway was a greater threat than the ground water pathway, and designed a sampling strategy to fully document resident population threat targets. For this site, installing wells may not be necessary, because the ground water pathway can be evaluated based on potential to release and potentially contaminated targets.

The expanded SI may be used to refine estimates of hazardous waste quantity by sampling bulk source materials, such as tanks or containers. Other work may be necessary to demonstrate the boundaries of surficial contamination or the total number of contaminated drinking water wells, particularly if several nearby residential properties are likely to be contaminated, not all of which were sampled during the focused **SI**.

Other considerations for expanded SI sampling include:

- **Collect samples to improve documentation for factors that significantly affect scoring:** For example, if background levels for ground water are in question—perhaps due to data of unknown quality—and a release to ground water is critical to scoring, the investigator may sample to ensure valid data.

- **Collect adequate background and QA/QC samples:** Demonstrating a release or a target exposed to actual contamination requires the full complement of background and QA/QC samples to adequately document information for NPL purposes. Background and QA/QC samples should not be limited by the sample budget— collecting these samples will prevent the need to return to the site. Section 4.3 discusses optimizing the number of QA/QC and background samples.

Field screening methods may be used during the expanded SI to further characterize the site, to identify CLP sample locations, or to support documentation requirements (e.g., designing soil sampling grids, selecting ground water well screen depths, and better describing the areas of surficial contamination). If soil samples need to be collected from adjacent residences or schools to document a sufficient number of resident population targets for the soil exposure pathway, field screening may be used to identify the samples submitted for CLP analyses.

Table 4-3 summarizes expanded SI sampling criteria and priorities to help the investigator plan and allocate samples for expanded SI objectives.

4.2 SOURCE CHARACTERIZATION

Characterizing sources generally requires collecting source samples to investigate the types of wastes deposited at the site and specifically to identify

TABLE 4-3: PRIORITIES FOR EXPANDED SI SAMPLES

SAMPLING CRITERIA	PRIORITIES
Number of pathways sampled	Sample pathways critical to site score If multiple pathways are critical to site score, sample to fully document all remaining site hypotheses
Number of targets sampled	Sample targets (e.g., drinking water wells and intakes, residential and school properties, surface water sensitive environments and wetlands) most likely to be exposed to site-related contamination Resample targets where previous analytical results are questionable, or where background concentrations are needed to document contamination of targets
Number of sources sampled	Sample sources to attribute hazardous substances to site Sample to more fully describe areas of observed surficial contamination If multiple source types exist at site, at a minimum, sample each different source type
Number of release samples	Sample to document a release for critical pathways. When possible, collect samples to document an observed release in conjunction with a target exposed to actual contamination Limit number of release samples to critical pathways
Number of background and QA/QC samples	Collect background QA/QC samples necessary to confidently document site score
Other criteria	User previous analytical data to optimize sample locations Do not resample at locations where reliable previous analytical data fully documented a hazardous substance or a release unless samples are needed to pair those with background samples taken at the same time

hazardous substances. Investigators should sample as many different types of sources as possible on the assumption that different hazardous substances will be found in different sources. A surface impoundment, for example, may yield different hazardous substances than a waste pile. Even if analytical data on hazardous substances are available, sources should be sampled to confirm the data. Source sampling could support attribution if the same hazardous substances or transformation products are detected in samples taken at release or target sample locations.

Samples from visibly contaminated soils may be more useful to characterize sources than samples from a specific drum or container because such samples may identify more hazardous substances. Also, sampling soils presents fewer safety issues than sampling containers. If little is known about historical site operations and no distinct sources exist, sampling where wastes are most likely to collect, such as onsite ditches, pools, drainage pipes, or other structures, may provide information on the types of substances previously handled. Historical aerial photos may

show prior disposal areas and changes to site features or topography affecting the location of wastes.

When submitting a source sample for CLP special analytical services (SAS), the Sl investigator should notify the laboratory of hazardous substances suspected in the sample, expected concentrations, and analytical protocols to be followed.

Table 4-4 compares the focused and expanded SI source sampling strategies.

4.2.1 Focused SI Strategy—Source Characterization

Identifying hazardous substances present at the site is a prime objective of the focused SI. Information on waste management practices or previous data from source areas can reduce the number of samples needed to characterize the sources. At the end of the focused SI, quality-assured analytical data (e.g., CLP data) should identify the specific hazardous substances

TABLE 4.4: SOURCE SAMPLING STRATEGIES

CRITERION	FOCUSED SI	EXPANDED SI AND SINGLE SI
Primary objective	To identify hazardous substances associated with site sources; to confirm substances known or suspected To refine target distance limits	To verify inconclusive data collected during focused SI In limited situations, to help quantify hazardous waste quantity
Data quality	All DUCs	DUC-I for hazardous constituent quantity DUC-I and DUC-II to establish heterogeneity or homogeneity of wastes All DUCs for other hazardous waste quantity measures and to identify hazardous substances associated with site sources
Sample to help demonstrate observed contamination	Generally limited to samples used to test a site hypothesis regarding soil contamination within 2 feet of surface	Samples to further describe the areas of observed contamination in the direction of targets for the soil exposure pathway
Samples to help evaluate sources containment or source type	Generally not collected	Generally only collected when the containment factor value for a migration pathway is not 10; sometimes collected to demonstrate a biogas release if air pathway is significant pathway
Samples to help describe source boundaries and estimate hazardous waste quantity	Generally limited to surficial samples within 2 feet of surface Generally limited to contaminated soil sources	In certain situations, samples to estimate the depth of a source or to further describe the area of sources other than contaminated soil (e.g., landfill, land treatment, buried surface impoundment) In certain situations, samples to estimate hazardous constituent quantity or hazardous waste volume quantity

at the site and confirm the presence of substances known or suspected during the PA.

Samples should not be collected to directly establish the degree of containment for a source. Containment generally can be evaluated accurately by field observations. Samples collected to identify hazardous substances, however, may also document poor source containment, if necessary.

Samples to support estimates of source volume, hazardous constituents, and source area are generally beyond the scope of the focused SI. For source types with reasonably well-defined boundaries (e.g., surface impoundments, waste piles), physical measurements taken with a steel tape measure or laser range finder should be used to determine area and possibly volume dimensions. Hazardous waste quantity factor values are determined by calculating a hazardous waste quantity for each source and then assigning a factor value for a range of waste quantities. The ranges for these values are quite broad, so that a small increase in quantity, unless near a breakpoint, could have no impact on the factor value assigned. For example, a measure of hazardous waste quantity for the soil exposure pathway is areal extent of observed contamination. More than 78 acres of contaminated soil would be needed to increase the hazardous waste quantity factor value above the minimum value. Rather than determining the full areal extent of contamination, samples should focus on documenting contaminated targets. The SI investigator should bear in mind that actual contamination in water or air may be sufficient for a site to qualify for the NPL (i.e., HRS score greater than 57 for a single pathway).

4.2.2 Expanded and Single Sl Strategy—Source Characterization

Source characterization sampling during an expanded and single SI should focus on HRS documentation requirements. As with the focused SI, background information on waste management practices or previous sampling efforts may significantly reduce the number of samples needed to investigate site sources. If data from site records and previous sampling investigations, including the focused SI, are of good quality, little or no source samples may be needed during the expanded SI.

Some samples used to identify hazardous substances may be used to document containment for a source. For some sites, limited samples may be collected during the expanded SI to evaluate the degree of containment for a source, or to determine whether the source is releasing methane or other biogases.

Sampling to document hazardous waste quantity estimates is generally beyond the scope of the expanded SI. Such sampling may be appropriate for some sources (e.g., containers such as drums and tanks with homogeneous wastes), but is generally not cost-effective given the wide ranges for hazardous waste quantity factor values and values that can be obtained using other tiers.

4.2.3 Example of Source Sampling Strategy

> Located near a town of 10,000 people, the Lakefield Farm Site is an abandoned strawberry farm that was used for various types of waste activities for an unknown period (Figure 4- 1). During the PA, three potential sources were identified: a wet surface impoundment with a volume of approximately 45,000 cubic feet of electroplating sludge; a drum storage area containing about 30 leaking drums, contents unknown, at the southeast comer of the site; and an area of stained soil near the site's western boundary.

As this example illustrates, understanding the scoring implications of the wide quantity ranges used to assign hazardous waste quantity factor values will help identify the samples necessary to determine substance-specific waste characteristics. Table 4-5 summarizes a suggested strategy to characterize the potential waste sources. For this site, it is reasonable to sample the soil underlying the drums, assuming it is representative of the drum contents. In general, when the contents of any container are unknown, the investigator should sample the soils near or beneath the source and not sample the contents of the source itself. Direct sampling of the containerized. sources requires specialized expertise, such as the Technical Assistance Team.

FIGURE 4-1: LAKEFIELD FARM SITE SKETCH #1

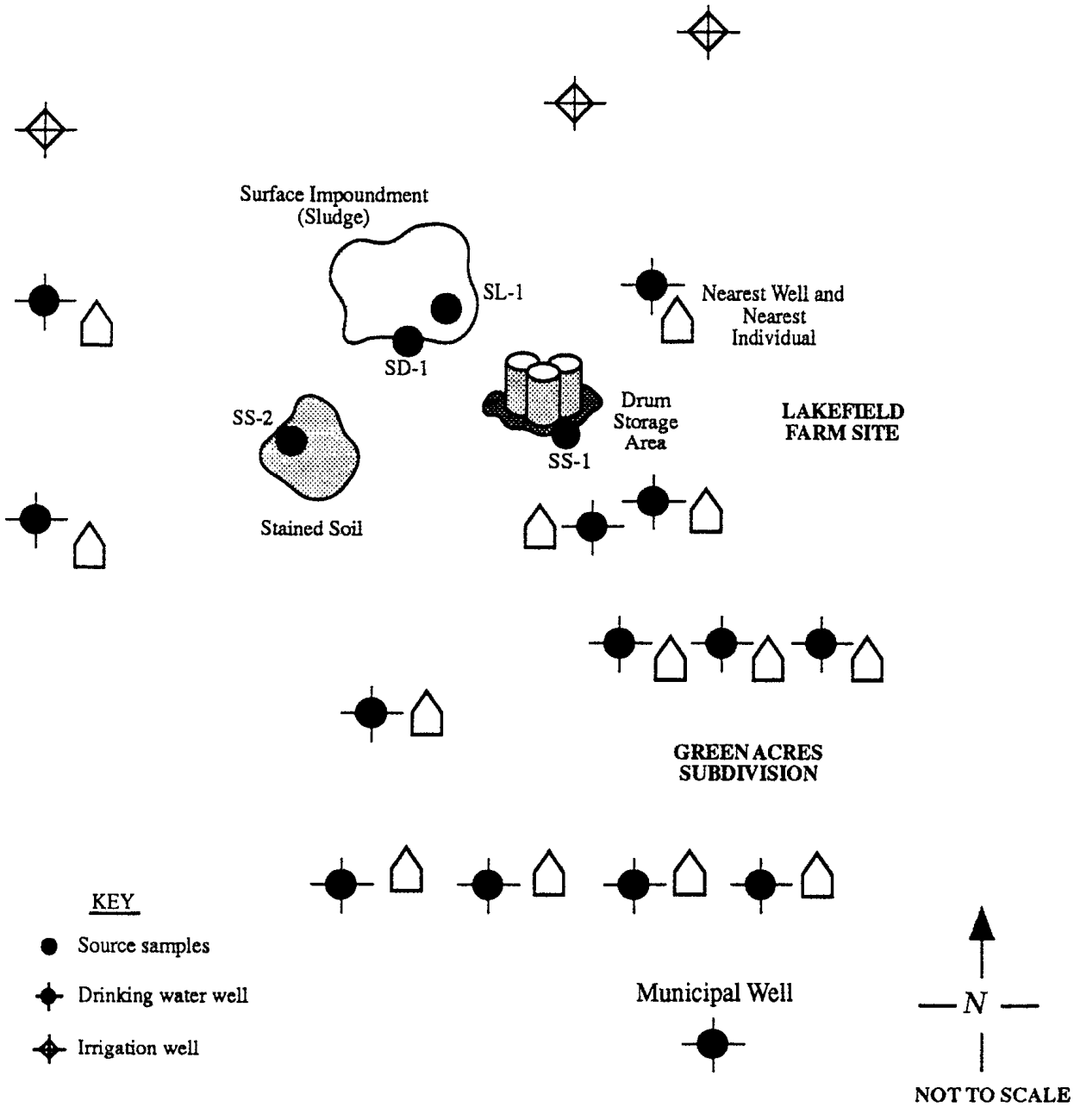


TABLE 4-5: SOURCE SAMPLING STRATEGY FOR EXAMPLE SITE

POTENTIAL WASTE SOURCE AREA	FOCUSED SI SAMPLING STRATEGY	HRS CONSIDERATIONS	NON-SAMPLING DATA COLLECTION
Wet surface impoundment	Collect 1 composite source sample of impoundment sediments (SD-1) plus one sludge sample (SL-1) to evaluate hazardous substances present	More than 675,000 cubic feet are needed to increase HWQ factor value to next category value	Obtain physical dimensions of source; evaluate containment. Consider using aerial photos
Drum storage area	Collect 1 composite surficial soil sample (SS-1) from beneath drums to determine hazardous substances present	More than 1,000 drums are needed to increase HWQ factor value to next category value	Verify number of drums; evaluate containment; look for container markings; examine area around drums
Stained soil	Collect 1 composite surficial soil sample (SS-2) to determine if area is contaminated and to identify hazardous substances	More than 78 acres of contaminated soil are needed to increase HWQ factor value to next category value	Obtain physical dimensions of area; evaluate containment

4.3 QA/QC SAMPLES

The investigator should collect appropriate QA/QC samples during the SI to confirm the collection of precise and accurate data that represent site conditions. EPA Regional guidelines suggest the number of QA/QC samples to collect. These samples (Table 4-6) should be collected, stored, transported, and analyzed in the same manner as the other site samples.

Several types of field QC samples may be used to monitor contamination of samples—for example, duplicate and split samples, as well as field and trip blanks (see Section 3.2). In general, 1 co-located and 1 replicate are taken for each 20 samples at a site. Some SIs will not require co-located or replicate samples if fewer than 20 samples are collected. Field blanks are required for ground water, surface water, and soil samples at the rate of 1 field blank per matrix per day, or 1 for each 20 samples at a site, whichever is fewer. Field blanks are not required for source material or air samples.

Trip blanks for each day of sampling are required for ground water, surface water, and air samples that involve volatile organics. Field matrix spikes are recommended only if the appropriate technical support is available. For some sites, an extra volume of liquid from a sample location is collected for matrix spike analysis; analysis of the spike is required by CADRE. If it is collected, the results should be compared with laboratory matrix spike results.

For both field and QA/QC samples, the investigator should be able to correlate results of specific sample analyses to those locations where samples were collected during the SI. During SI field work, the investigator should record information regarding sampling activities and observations, including sampling protocols and locations, as well as pertinent physical and topographic features of the site. A map showing sample locations, contaminated areas, and other features pertinent to data evaluation should be provided. In addition, notations concerning the SI samples should be made by either the investigator or the laboratory—for example, whether a sediment

TABLE 4-6: GUIDELINES FOR MINIMUM QA/QC SAMPLES EXPANDED SI OR SINGLE SI

MEDIUM	REPLICATES/ DUPLICATES	FIELD BLANKS	TRIP BLANKS
Aqueous	1 in 20	1 in 20	1/day of sampling
Soil and sediment	1 in 20	1 in 20	Usually not required
Air	1 in 20	Not applicable	1/day of sampling
Source material	1 in 20	Usually not required	Usually not required
Sample requirements should be developed on a site-specific basis. Laboratory blanks and spikes are method-specific and are not included in the table.			

sample had coarse grains or fine grains, or whether a ground water sample was muddy or clear. These notations should accompany the data during reporting. Analytical data should be accompanied by a table or matrix that correlates field sample numbers with laboratory sample numbers.

Reported data should indicate whether samples were filtered or unfiltered. This information may be needed to compare background levels with site samples and to compare sample data with media-specific benchmarks.

4.3.1 Focused St Strategy—QA/QC Samples

During the focused SI, only a few QA/QC samples should be collected to ensure that sample results have not been influenced by contamination introduced during field activities. Focused SI QA/QC samples might consist of one trip blank for each day of sampling activities along with one equipment rinsate blank for each matrix sampled. Blanks serve to indicate false positive sampling results, and to monitor the field team's sample handling and decontamination procedures.

At sites where both soil or sediment and aqueous samples are collected, the SI investigator should consider using only the aqueous trip blank and eliminating the soil or sediment trip blank. Aqueous blanks, unlike soil or sediment blanks, are used to detect organic and inorganic contamination. Generally, contamination introduced by improper field activities is more easily detected in the water matrix. The focused SI may also require one rinsate for soil or sediment sampling equipment and one rinsate for water sampling equipment.

Duplicate samples for data validation generally should not be collected during the focused SI since precision of the data generally will not affect the screening decision. Thus, a limited number of QA/QC samples may be sufficient to support focused SI objectives. Generally, these samples should represent 10 to 15 percent of the total number of samples collected.

4.3.2 Expanded and Single SI Strategy—QA/QC Samples

During the expanded and single SI, the full complement of QA/QC samples should be collected to ensure data of rigorous quality. In contrast to the focused SI strategy, duplicate samples for data validation may be appropriate to monitor the precision of the analytical data. Trip blanks should be collected for all media sampled during the expanded SI. If hazardous substance concentrations likely are to be near detection limits or near media-specific benchmarks, multiple samples at critical locations may also be appropriate.

In summary, a greater number of QA/QC samples may be necessary to support expanded SI objectives. As a general rule, these samples are 15 to 25 percent of the total number of samples collected.

4.4 SAMPLE TO DEMONSTRATE A RELEASE

4.4.1 General Principles

This section discusses three considerations for sampling to demonstrate a release or observed contamination—background, attribution, and target—followed by focused and expanded SI strategies. Table 4-7 compares SI strategies to investigate a release.

To demonstrate a release by chemical analysis for a pathway, at least one sample must show contamination significantly above the background level for a hazardous substance. In the absence of any other evidence, the sampling strategy should generally specify collecting at least two samples from each appropriate pathway to demonstrate a release:

- One sample representative of background levels
- One sample downgradient (or downslope, downstream, downwind) of the source of contamination

Since concentrations of hazardous substances usually decrease with distance from sources, sampling near sources may also help to distinguish between alternative sources of contamination in the vicinity of the site.

Background Sampling Considerations

Establishing a release requires evaluating background. Background is the ambient concentration of a hazardous substance and includes naturally occurring concentrations, concentrations from man-made sources other than the site being evaluated, and concentrations from the site. Generally, background levels are best supported by chemical analysis.

Background and release samples and analyses should be similar, and should focus on the comparability of samples in representing target impacts. To establish background by chemical analysis, the location and number of background samples depends on:

- Hazardous substances present at the site and expected concentrations
- Availability and quality of previous information and analytical data
- Objectives of the investigation
- Site hypotheses to be tested
- Media variability
- Size of the site and number of sources types
- Pathway-specific considerations (e.g., geologic formations, types of surface water bodies)
- Other potential sources of contamination in the vicinity of the site

TABLE 4-7: OBSERVED RELEASE SAMPLING STRATEGIES

CRITERION	FOCUSED SI	EXPANDED SI AND SINGLE SI
Objective	To test hypothesis (suspected release)	To demonstrate a release based on HRS documentation requirements
Data quality	Less rigorous (e.g., DUC-II) to rigorous (e.g., DUC-I)	Rigorous (e.g., DUC-I)
Background samples	Limited, 1 background to 3 release samples May rely on published regional data	2 background to 3 release samples Generally should not rely on published data to establish background levels
Attribution samples	Limited to what is necessary to test hypothesis (suspected release)	Those necessary to attribute a portion of a release to the site being evaluated
QA/QC samples	Limited to what is necessary to test hypothesis (suspected release)	Those necessary to obtain precise and accurate data within the scope of the SI

In some situations, appropriate background sample collection may not be possible—for example, no sample could be taken that would represent surface water background levels for comparison with sample concentrations from an isolated pond adjacent to a site. In other situations, background samples may not be needed. For instance, if sample results over a period of time indicate that a well was once uncontaminated and is now contaminated, that well can establish its own background and release levels. Also, some man-made hazardous substances (e.g., chlorinated organic solvents, short-lived radioactive substances) are not naturally occurring or ubiquitous and can only be attributed to a man-made source. If the site is the only source of these substances, the background levels are assumed to be zero (or below detection).

An SI may not require sampling to establish background levels of a specific hazardous substance if the following conditions are met:

- The specific substance is known to be present at the site based on previous analytical data, historical records, or other information such as written statements.
- The specific substance is not known to be naturally occurring or ubiquitous.
- No other sources of contamination for that substance are identified in the vicinity of the site (particularly for nonindustrial areas).

The HRS documents an observed release in one of two ways:

- **Direct observation:** Material containing a hazardous substance is observed entering or is known to have directly entered the medium (i.e., ground water, surface water, or air) from the site (e.g, through direct deposition of substances below the water table, or an outfall discharging to surface water).

- **Chemical analysis:** Analytical evidence of a hazardous substance in a medium at concentrations significantly above the background level where a portion of the significant increase is attributable to site sources.

Potential background sample locations include nearby wells that are not expected to be influenced by the site or sediments from non-tidal surface water bodies upstream from the probable point of entry (PPE) to surface water. Background samples for each pathway are discussed in Sections 4.5 through 4.8.

Analytical data near method detection limits and qualified sample results complicate the use of background sample data. During the expanded SI, collecting additional background samples from representative locations may increase the confidence in determining the presence or absence of site contamination.

Some hazardous substances (e.g., lead, arsenic, copper) occur naturally in many areas. If they are used in scoring, background levels are best supported by samples of representative ambient conditions. Without site-specific background data, background levels may be based on other data for naturally occurring concentrations of the substance. The investigator should consider the following sources of information:

- Background sample data for other nearby CERCLA site investigations
- Local surveys by other Federal or State agencies (e.g., Soil Conservation Service, USGS, BLM, mining industry)
- Local universities (e.g., graduate theses)
- Natural concentration ranges and averages in Soil

Published naturally occurring ranges of common metals and inorganics may sometimes be used to determine background levels and to assess whether site-specific substance concentrations are indeed representative of regional background variability. However, published values may not account for regional variations or unique site-specific characteristics. Even when concentration data from scientific literature may not be appropriate to establish a background concentration for the site, such data may be used to plan SI samples and to support data interpretation.

As a general rule, the investigator should use background concentration data from this sampling investigation. However, in the absence of data generated from a SI, published data may be used to

establish background levels if documentation indicates that the published background data and the sample data showing contamination have similar characteristics, or are influenced equally by alternative sources of contamination. For the focused SI, site-specific background data are less essential.

Attribution Considerations

To demonstrate an observed release, some portion of the release must be attributable to one or more sources at the site. Where attribution of hazardous substances is questionable, sampling should be designed to produce analytical data that demonstrate the site to be at least partially responsible for the contamination. Contributions from other sources of contamination may be differentiated by identifying a single hazardous substance that is unique to the site being evaluated (e.g., wastestream "fingerprinting"). This may require specific analysis and specific review of the data.

In many cases, the site being evaluated is not the only source. Complex attribution concerns (e.g., widespread ground water contamination involving several substances, soil contamination in an industrial area, sediment contamination in harbors) may require investigation better suited to the expanded SI. However, if attribution is not complex, it can be addressed during the focused SI. For many sites, attribution concerns may be addressed by characterizing sources at the site.

Target Considerations

When evaluating actual contamination, particularly the level of human food chain contamination (see Section 4.6), the investigator should note any potential for sampling errors and false assumptions affecting data representativeness. If the concentration of a hazardous substance meets actual contamination criteria and equals or exceeds its benchmark concentration, the sample location is considered subject to Level I contamination for that pathway or threat If media-specific hazardous substance concentrations analyzed in the target sample meet the criteria for actual contamination for the pathway but are less than the media-specific benchmark, or if none of these hazardous substances have an applicable benchmark, Level II concentrations apply. Special "I"and "J" indices, based on screening concentrations, are calculated when no hazardous substance individually equals or exceeds its benchmark concentration, and when more than one hazardous substance meets the criteria for actual contamination for the sample (or comparable samples). If either index equals or exceeds 1, Level I concentrations apply for the sample location.

Under certain circumstances, sample data that are biased high may be used to score an observed release, but such data must only be used to establish Level II contamination, not Level I contamination and not hazardous waste quantity Tier A.

In the HRS, significance relates only to the concentration found in a pathway, not to any health or environmental effects. A release may be below the recommended regulatory action level and still constitute an observed release. If the site qualifies for the NPL, remedial studies will determine the risks associated with the release and appropriate corrective actions. The criteria used to determine analytical significance include the following:

- A sample measurement confirms that the release is equal to or greater than the sample quantitation limit (SQL). The SQL is the amount of a hazardous substance that can be reasonably quantified, given the limits of detection for the methods of analysis and sample characteristics that may affect quantitation (e.g., dilution, concentration).

- If the background concentration is not detected or is less than the detection limit, a release is established if the sample measurement equals or exceeds the SQL. For HRS purposes, the detection limit used is the method detection limit (MDL) or the instrument detection limit (IDL) for realtime field instruments.

- If the background concentration equals or exceeds the detection limit, a release is established if the sample measurement is at least three times the background concentration and attribution is established.

4.4.2 Focused SI Strategy–Sample to Demonstrate a Release

Focused SI sampling does not require fully documenting observed releases, which often involves extensive background sampling as well as sampling to rule out other sources of contamination. To demonstrate a release, analytical data must indicate that a hazardous substance is present at an elevated level and is related to the site. Sampling to demonstrate actual target contamination also investigates a release hypothesis. The scope of the focused SI does not require collecting the full complement of background and field QA/QC samples, which can total as much as 30 percent of all samples for a complete listing investigation. Sampling to document attribution is typically an expanded SI activity. However, the focused SI can include some background and QA/QC samples, according to Regional or State guidelines, to increase the investigator's confidence in the quality and representativeness of analytical results.

Focused Sl sampling should concentrate on providing evidence of contamination in the ground water and surface water pathways where a release was suspected during the PA. Also, samples should be collected to support or refute the presence of surficial contamination for the soil exposure pathway. Air sampling is an expanded SI activity.

4.4.3 Expanded and Single Sl Strategy—Sample to Demonstrate a Release

Expanded SI sampling should focus on demonstrating and documenting a release based on data of rigorous quality. The full complement of background, QA/QC, and attribution samples should be collected. In contrast to the focused SI, which tests the hypothesis of a release, expanded SI sampling should meet HRS documentation requirements for a release. The expanded SI should also include samples linking the presence and migration of hazardous substances to sources at the site.

Representative background samples may be difficult to collect if the sample medium is heterogeneous and the background samples are subject to interference from alternative sources of contamination (e.g., urban soils). If any existing background samples are subject to potential interference, the investigator should determine if they accurately represent background conditions by assessing whether the interference:

- Affects background and release samples significantly;
- Affects background and release samples equally;
- Affects background and release samples; and unequally and bias can be determined.

If the interference is insignificant, background samples from previous investigations may be used. Likewise, if both samples are affected equally, previous background data may be appropriate. If the samples are affected unequally, previous background concentrations biased high may be used; background concentrations that are biased low should not be used.

4.5 GROUND WATER PATHWAY

The ground water pathway score and the aquifers and wells to be sampled depend on the:

- Number of people served by each aquifer
- Likelihood of a release to each aquifer
- Likelihood that drinking water wells are contaminated by the site

To document a release to ground water by direct observation, material containing one or more hazardous substances must be known to have entered ground water through direct deposition or must be seen entering ground water. Direct deposition establishing a release may include injection and deposition of hazardous substances below the water table. In most cases, chemical analysis of ground water samples from an aquifer is preferred to establish a release.

To document whether a population is drawing from a contaminated drinking water supply, the analytical results must demonstrate a release to the pathway by

> If SI targets include municipal wells hypothesized to be exposed to actual contamination, the investigator should review well monitoring data under the Safe Drinking Water Act to determine if the well has been properly monitored and if adequate data exist to determine whether the well is contaminated.

HRS criteria. A. drinking water well and its background well must be finished in the same aquifer and screened in a comparable zone.

Filtration of ground water samples for metals is one way to reduce the turbidity of highly turbid samples due to rushed well construction practices. However, if some samples are filtered, other samples should be filtered to ensure comparability. Unfiltered samples may be used to establish a release for many hazardous substances.

When sampling ground water, the investigator should:

- Collect the appropriate types of water samples.
- Collect only unfiltered metals samples from karst aquifers;
- Collect only unfiltered water samples for the analysis of organic substances;
- Collect background well samples from the same aquifer as the wells used to establish a release;
- Verify that samples are representative of the ground water at that location;
- Verify that the sample is not altered or contaminated by sampling and handling procedures; and
- Clearly designate whether data derived from the samples are from filtered or unfiltered samples.

If the wells are screened, the well screen intervals must be in the same aquifer, particularly when water occurs within small lenses isolated by clay segments in surrounding material (e.g, glacial terrain).

Even if interconnection of aquifers has been established, both background and release wells must be completed in the same aquifer. For example, a background sample from a bedrock aquifer must not be compared with a sample from a surficial alluvial aquifer, even though the two are hydrologically connected.

To the degree possible, background and observed release samples should be taken from approximately the same depth in the aquifer of concern. In determining depth, the investigator should consider elevation relative to a reference (e.g., mean sea level) rather than depth below the ground surface.

To the degree possible, well completion techniques should be similar for background and observed release wells. Because some hazardous substances adsorb to suspended matter, unfiltered water samples from separate wells that vary in suspended matter concentration may not be comparable. For example, an older drinking water well may provide water containing very little suspended matter, while a new or incomplete monitoring well may yield samples containing substanfial suspended matter.

Background and release samples are best collected within 1 to 3 days. Background wells should be outside the influence of sources at the site. Ground water samples should not be affected by artifacts of sampling equipment or procedures.

4.5.1 Focused SI Strategy—GroundWater Pathway

Sampling to establish observed release is not necessarily a focused Sl objective. Documenting an observed release for the ground water pathway according to the HRS may require installing monitoring' wells, which is beyond the scope of the focused SI. If background data are critical to the site screening recommendation and no applicable wells exist, the investigator could establish background through one of the following:

- Published data on regional ground water quality
- Samples from a well potentially less influenced by the site (e.g., a more distant well)
- Reliable previous data from a nearby site

Every well identified as a primary target need not be sampled during the focused SI. The investigator should review PA scoresheets to select drinking water well sample locations most likely to detect hazardous substances. Investigators should sample existing wells if they are strategically located for critical site decisions.

If a release to ground water was hypothesized during the PA, the SI investigator should sample the nearest well suspected of contamination. If contamination of drinking water was hypothesized and the nearest well is not a drinking water well, sampling the nearest drinking water well in addition to the nearest well would be a feasible strategy; sampling the nearest drinking water well may be more informative and could serve to test both the release and contaminated target hypotheses.

If actual contamination of drinking water wells is suspected, these wells should be sampled during the focused SI to test hypotheses and determine die level of contamination. If sampling every drinking water well suspected of contamination is not possible, nearby wells, especially municipal wells, should be sampled if there is a reasonable probability of detecting a release and target exposure. Additional sampling to more clearly define all contaminated drinking water wells may be conducted during the expanded SI, if necessary.

If a blended municipal water supply system has more than one well within 4 miles of site sources, the SI investigator should sample the nearest well of the system. If the direction of ground water flow is uncertain, the nearest wells reasonably expected to have contamination attributable to the site should be sampled. The investigator may also want to sample additional drinking water wells to ensure protection of public health.

Nearby wells drawing from the aquifer and screened at similar depths are potential background sample locations. The wells may be monitoring, private, public, industrial, or irrigation wells. The SI investigator can compare analytical results from drinking water wells with these background wells.

Background samples may not be necessary during the focused SI to confirm whether hazardous substances have migrated from some sites. For example, if the hazardous substances associated with the site are not naturally occurring and no other potential sources exist in the area, the focused SI investigator should collect the minimum number of background samples to screen the site. In this example, the focused SI investigator need not collect any background samples.

4.5.2 Expanded and Single SI Strategy– Ground Water Pathway

The expanded SI ground water pathway investigation should begin with a careful review of existing analytical data from wells within the vicinity of the site. The SI investigator should review existing data to identify abnormalities and any required resampling. For example, if a background sample contains an unusually high level of metals, the investigator should suspect artificially induced sample contamination (e.g., entrained sedimentp.) and should review the data with the program staff responsible for collecting and analyzing the sample to determine if the contamination warrants resampling.

Samples from existing wells finished in the aquifer being evaluated or installation of monitoring wells may be necessary if no reliable data exist. The wells being evaluated for a release should also be finished in that aquifer and screened at a depth comparable to the background well. Multiple wells should be selected to increase the likelihood of intercepting the contaminated plume.

In most cases, a ground water background sample will be needed, requiring samples from a minimum of two wells to document a release. The selection of these wells depends on the direction of ground water flow. To determine flow direction, the investigator can:

- Install piezometers;
- Compare static water-level elevations in a series of wells completed in the same aquifer,
- Review published hydrogeologic reports; and
- Examine evidence of other previously investigated nearby ground water contamination.

One well in the aquifer being evaluated should generally be upgradient of the site to serve as a background measure. While an upgradient background well is preferred, any well outside (or, in some cases, within) the influence of sources at the site can be used to establish background levels.

If background wells are not available, a spring sample collected before the ground water reaches the surface may be used to establish background. A pipe should be inserted near the point of ground water discharge at the spring. The investigator should accurately document the sampling procedure in the field logbook. Table 4-8 compares the focused and expanded SI ground water sampling strategies.

Well Installation

Monitoring wells should not be installed unless they are necessary for the site score to be 28.50 or greater based on an observed release. It may not be necessary to document a release if the site will score 28.50 or greater due to other major pathways, or if

TABLE 4-8: GROUND WATER SAMPLING STRATEGIES

CRITERION	FOCUSED SI	EXPANDED SI AND SINGLE SI
Primary objective	To test hypotheses regarding a suspected release or targets suspected to be exposed to actual contamination When possible, test release hypothesis in conjunction with target sampling	To demonstrate a release based on HRS documentation requirements To demonstrate targets exposed to actual contamination and determine levels of exposure
Data quality (see section 5.2)	Less rigorous (e.g., DUC-II) to rigorous	Rigorous (e.g., DUC-I)
Average number of samples	0 to 6 depending on site hypotheses and number of existing wells to sample	0 to 14 based on HRS documentation requirements
Types of activities	Sample existing wells Install drive points or shallow boreholes if there are no nearby wells	Resample existing wells if previous data did not conclusively demonstrate a release or targets exposed to actual contamination Sample wells not yet sampled Collect multiple samples from drinking-water wells where hazardous substance concentrations are likely to be near benchmarks Install monitoring wells as needed
Background samples	Limited, 1 background per 3 release samples May rely on published regional data	2 background per 3 release samples Install background monitoring wells, if necessary Generally should not rely on published data
Attribution samples	Limited to testing release hypotheses	Those necessary to attribute a share of a release to the site
QA/QC samples	Limited to testing release hypotheses	Those necessary to obtain precise and accurate data

the ground water pathway already scores high based on potential to release. Before deciding to install wells, the investigator should also consider:

- Unknown source of the contamination in nearby wells
- Depth to aquifer and type of geologic materials underlying site sources
- Likelihood of detecting contamination in the monitoring wells
- Installation costs
- Public health concerns

DNAPLs - A Special Case

Dense nonaqueous phase liquids (DNAPLs) are separate-phase hydrocarbon liquids that are denser than water, such as chlorinated solvents, wood preservative and coal tar wastes, and pesticides. DNAPLs, also known as sinkers, move downward under the influence of gravity until reaching a less permeable formation where they may accumulate, move down-slope, or penetrate fractures. Special precautions need to be taken at sites with DNAPLs to ensure that drilling does not induce the spread of free-phase DNAPL contamination. Drilling should be suspended when a low-permeability unit or DNAPL is encountered. Fine-grained aquitards (such as clay or silt) should be assumed to permit downward migration of DNAPLs. For guidance on sites with potential DNAPL contamination, see *Estimating the Potential for Occurrence of DNAPL at Superfund Sites,* OSWER Directive 9355.4-07FS, 1992.

The primary objective of installing wells is to collect ground water data that can be used to establish a release. Other goals are beyond the scope of the SI—for example, to delineate a hazardous substance plume or track movement of a substance.

During monitoring well installation, the field team geologist should prepare a drilling log. The log should describe the general texture, color, size, lithology, and depth of the geologic materials encountered during drilling. Information obtained during well installation may be used to document potential to release factors, including lithology, hydraulic conductivity, travel time, and depth to aquifer.

Caution should be exercised when correlating data between drill holes. Extrapolations of data more than 20 feet apart are not acceptable in nonhornogeneous geologic environments. To assess the homogeneity of the subsurface geology, site-specific data should be compared to regional geologic information.

Drilling can create interconnections between karst aquifers. Installing wells in a karst aquifer is generally not recommended due to the high likelihood of introducing hazardous substances into karst aquifers.

4.5.3 Example of Sampling Strategy

> The PA determined that residents near the Lakefield Farm Site rely on shallow domestic wells for drinking water. A municipal well that provides drinking water to about 10,000 people is located 0.5 mile southeast of the site. The municipal well and several nearby irrigation wells are screened in the deep aquifer, which appears to be interconnected with the shallow aquifer. The PA identified all domestic wells within 0.25 mile of the site and the municipal well as primary targets. The focused SI indicated ground water flows to the south. Several domestic wells appear to be downgradient from the site (Figure 4-2).

The SI investigator and EPA Regional site assessment manager planned a two-stage Sl for this site because of the large number of ground water targets and the lack of reliable previous information. Based solely on the ground water pathway, the site will not score greater than 28.50 if evaluated on potential to release, given the maximum waste characteristics score this site could receive (18), and potentially contaminated ground water targets. The site will not score above the cutoff unless the municipal well (Sample GW-12) or four domestic wells, as well as domestic wells in the Green Acres subdivision, are exposed to actual contamination. Based on these considerations and source conditions described earlier, the focused Sl required 18 samples—1 municipal well, 9 private wells, 4 source, 2 background, and 2 QA/QC—to test site hypotheses. If these wells are not contaminated, Lakefield Farm may not require further Superfund investigation.

Background conditions for the municipal well could be established by sampling the irrigation wells north of the site (GW-1 and GW-2), which draw from the deeper aquifer. Background samples might also be collected from the shallow aquifer to compare samples from the domestic wells. Field blank and equipment rinsate samples could be collected for QA/QC. Table 4-9 summarizes the suggested focused

FIGURE 4-2: LAKEFIELD FARM SITE SKETCH #2

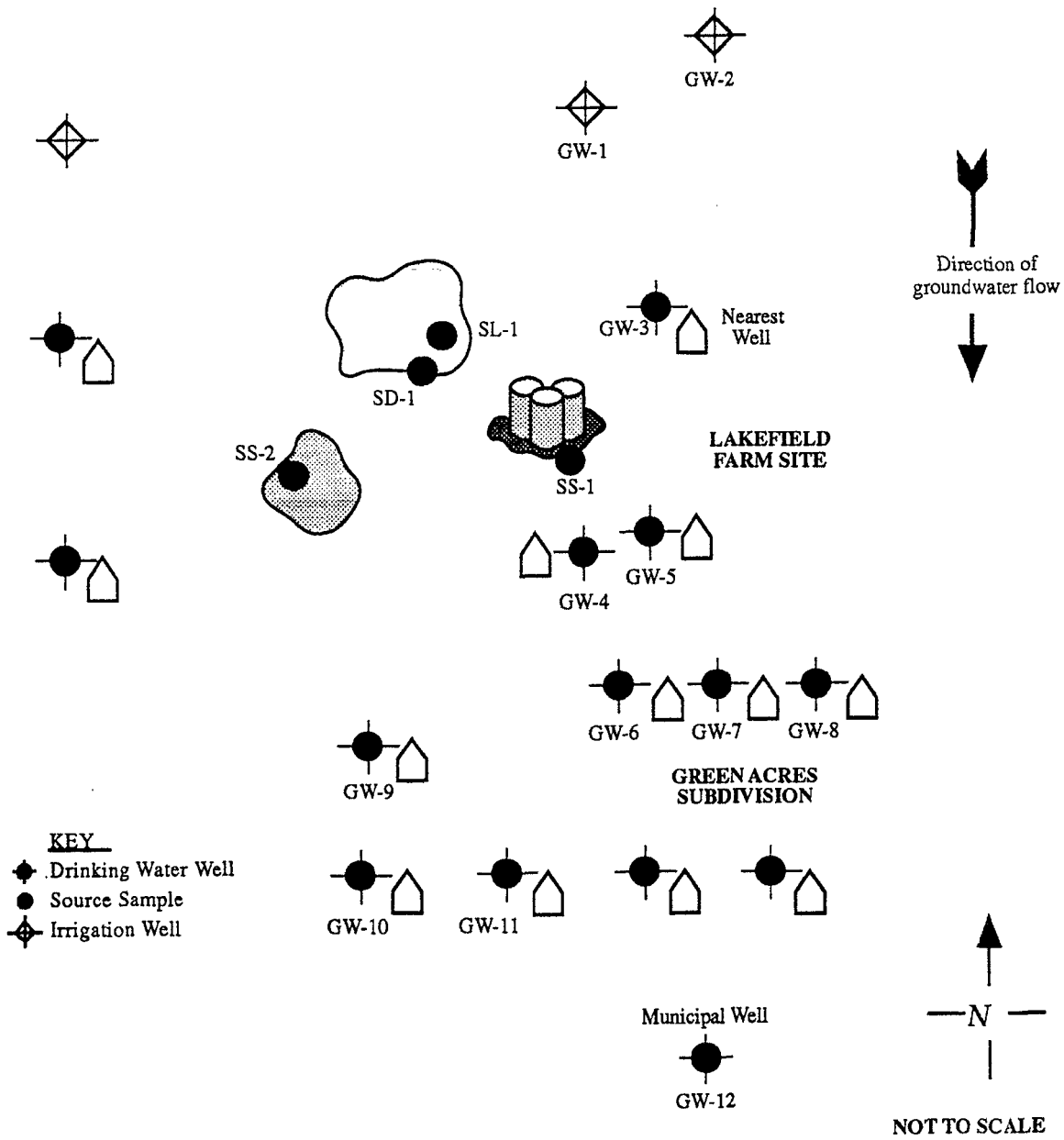


TABLE 4-9: GROUND WATER SAMPLING STRATEGY FOR EXAMPLE SITE FOCUSED SI

SAMPLES	SI SAMPLING STRATEGY	HRS CONSIDERATION	NON-SAMPLING DATA COLLECTION
Municipal well (GW-12)	Collect sample prior to treatment; sample to document contamination, identify hazardous substances, and determine level of contamination	Determine municipal well contamination, which is critical to protecting public health and the screening decision	Verify aquifer from which well draws; verify population served
Domestic wells (GW-3 through GW-11)	Sample nearest domestic drinking-water wells suspected of exposure to contamination	Determine domestic well contamination, which is critical to protecting public health and the screening decision	Verify aquifer from which wells draw; verify population served
Background (GW-1, GW-2)	Sample drinking water aquifer; limit number of background samples	Sample to determine concentrations of hazardous substances	Verify aquifer from which well draws
Sources (SD-1, SL-1, SS-1, SS-2)	Collect grab or composite soil samples to identify hazardous substances present at site	Do not sample to increase hazardous waste quantity (amounts are not close to HWQ factor value breakpoints)	Obtain physical dimensions of surface impoundment and estimate area of contaminated soil; verify number of drums and look for drum labels
Quality control (Q-1, Q-2) (Not shown)	Monitor sample collection and decontamination procedures; 1 rinsate and 1 field blank		

SI sampling strategy. Other focused SI considerations include:

- Collecting a second sample from the municipal well to increase the chance of documenting contamination;
- Collecting additional samples to demonstrate background conditions;
- Verifying ground water flow direction by measuring water levels in wells; and
- Checking if contamination has been demonstrated in the deep aquifer within 2 miles of the site.

For this example, assume that focused SI sample results indicate that the municipal well sample was not contaminated, but one ground water sample (GW-4) showed elevated concentrations of a hazardous substance also found during source sampling. Based on these results, the site score is not greater than the cutoff score: the site is screened from further Superfund consideration; and the expanded SI may not be necessary. The focused SI met its objectives, and EPA can refer the site and the contaminated domestic well to the appropriate authorities (e.g., removal program or State authorities).

As a variation to this example, assume that two domestic wells south of the site were closed prior to the SI due to contamination by volatile organic compounds (VOCs), and just east of the site are two facilities that use solvents. In this scenario, it is uncertain whether Lakefield Farm has contributed to ground water contamination. Monitoring wells may need to be installed to attribute a portion of the contamination to the site. If ground water is the only significant pathway, and because attribution is critical to determine whether this site requires further Superfund attention, installing these wells may be planned as a single Sl that bypasses the focused SI.

4.6 SURFACE WATER PATHWAY

In general, sample locations for the surface water pathway include rivers, brooks, or streams flowing through or adjacent to a source, as well as bodies of water that may receive overland runoff or leachate. Before identifying sample locations, investigators should determine whether overland runoff or ground water discharge to surface water can result in contamination of a surface water body. The likely overland runoff pathways may be determined by reviewing the drainage network in the vicinity of the site. Generally, if there are no surface waters within 2 miles of the site, the surface water pathway need not be evaluated.

The investigator should review the physical characteristics of the surface water migration route. Some hazardous substances mix and disperse rapidly in turbulent waters, while others may remain as a plug or plume for longer distances in less turbulent waters. The latter may reach a surface water target while still concentrated. The SI investigator should consider the influence of conditions such as rocky bottoms, rapids, and meanders on the likelihood of detecting hazardous substances.

The types and locations of water bodies near the site and the persistence of hazardous substances should be considered when developing the surface water sample plan. For abandoned or inactive sites, collecting sediment samples may be more appropriate than collecting aqueous samples. Flow rate is also a consideration because high-volume flows tend to disperse and dilute hazardous substances more quickly than low-volume flows.

An observed release to surface water may be documented through direct observation if material containing hazardous substances are:

- Seen entering surface water;
- Known to have entered surface water through direct deposition; or
- Present in a source area in contact with surface water through flooding.

A single, short-duration discharge of hazardous substances to surface water may establish a release, even without upstream and downstream samples. Leachate flowing from a source into surface water and an outfall from a surface impoundment discharging to surface water are examples of direct deposition into surface water. In these cases, samples (or other analytical evidence) should be collected to show that the leachate and outfall materials contain a hazardous substance.

Some analytical results will be compared with mediaspecific benchmarks. For drinking water targets suspected to be subject to actual contamination, samples (either aqueous, sediment, or sessile benthic) should be collected at or downstream of the targets to score Level I or Level II contamination. Only aqueous samples can be used to score Level I drinking water targets; aqueous, sediment, and sessile benthic organism tissue samples can be used to score Level II. Surface water samples that cannot demonstrate Level I contamination may still be used to support Level II contamination. Table 4-10 summarizes the types of samples for each surface water pathway threat and the level of actual contamination each sample type can support.

If documenting actual human food chain contamination is essential to the site recommendation, sediment samples should be considered in preference to catching and analyzing organisms. Tissue samples of aquatic food chain organisms may be collected during the expanded SI, if necessary, to evaluate immediate health and environmental threats. Prior to collecting samples, the investigator should review HRS guidance and food chain threat benchmarks for those substances expected to be present in fish tissue and benthic organisms. Sessile benthic human food chain organisms include mussels and oysters. Nonsessile benthic organisms include crabs, snails,

TABLE 4-10: SURFACE WATER SAMPLES TO SUPORT A RELEASE AND TARGET CONTAMINATION

HRS Factors	Sediment[1]	Aqueous	Effluent[2]	Sessile Benthic Organisms	Non-sessile Benthic Organisms	Finfish, Amphibians, and Reptiles
Observed release	Yes	Yes	Yes	Yes	No	No
Level I drinking water	No	Yes	No	No	No	No
Level II drinking water	Yes	Yes	Yes	Yes	No	No
Level I sensitive environments	No	Yes	No	No	No	No
Level II sensitive environments	Yes	Yes	Yes	Yes	No	No
Level I fisheries	No	No	No	Yes[3]	Yes[3,4]	Yes[3,4]
Level II fisheries	Yes[5]	Yes[5]	Yes[5]	Yes[3]	No	No

[1]No benchmarks available; evaluate as Level II contamination.
[2]Does not require comparison to background to document a release.
[3]Sample only tissues of edible species to evaluate human food chain level of contamination.
[4]Can be used to score Level I targets, but not an observed release; must be collected within boundaries of surface water contamination.
[5]Targets can be evaluated if hazardous substance has a bioaccumulation factor value of 500 or greater.

crayfish, and lobsters. Examples of other aquatic human food chain organisms include fish, frogs, and eels. Samples may be collected at any point within or beyond a fishery boundary to evaluate actual human food chain contamination.

For water bodies where fishing is prohibited, if a hazardous substance for which the fishery was closed is found in a release sample within the boundaries of the closed fishery, samples from the water body can be used to score actual contamination even though no human food chain organism presently exists.

For the environmental threat, samples should be collected at, or downstream of, wetlands and other sensitive environments suspected of contamination. Only aqueous samples can be used to score Level I environmental contamination. If the investigator suspects that a wetland is exposed to contamination, in addition to samples near the PPE, two samples should be collected from the wetland which are at least 0.1 mile from the PPE into surface water. Data from unfiltered surface water samples should be compared to ecologically-based benchmarks.

Unfiltered samples may be used to establish a release. Water samples collected to analyze organic substances do not have to be filtered for comparison with drinking water benchmarks.

Special precautions should be taken to ensure that samples are representative of the surface water at that location, and that the sample is not altered or contaminated by sampling and handling procedures. Background samples should be collected in the same water body as samples used to investigate a release for example, the investigator should not compare a background sample from a small tributary and a release sample from a major river. In addition, chemical and physical properties of surface water can vary considerably within a small area. The lack of mixing in large, slowly flowing segments of rivers

may affect background levels. Also, chemical transformations, biological influences, and physical transport mechanisms may affect surface water quality. Background and release samples should be collected during the same time period.

Other sampling considerations include:

- Weather conditions affecting streamflow
- Grain size, organic content, and structure of sediments

Higher streamflows generally carry more suspended solids but may dilute some dissolved substances. Streamflow volume and dilution may vary following heavy rainfall or snow melt. Some types of sediments may adsorb substances to a greater extent than others. For example, fine clay particles may adsorb metals to a greater extent than larger particles.

When investigating actual contamination or an observed release, the investigator should be aware of potential sampling errors and false assumptions affecting data representativeness. Such considerations are especially important when establishing actual contamination and determining level of contamination in the human food chain.

If necessary, an observed release can be established based on the chemical analysis of tissue samples from sessile benthic organisms. Samples of similar tissue should be obtained to document background. Comparing dissimilar tissues—for example, liver tissue and muscle tissue—may yield false positive of false negative results (i.e., significant differences between background and release samples attributable to tissue types rather than a release). Edible tissue samples are more appropriate for evaluating human health threats via the food chain. Where edible tissue samples are not available, the following is a hierarchy of preference for other sample types:

- Edible tissue samples with associated tissues attached or only partially removed
- Whole-body samples
- Samples of other specific tissues or organs

Samples should be obtained from the same species and from organisms of similar ages. As with other surface water samples, the investigator should descriptively document sample locations and note possible sources of influence on the analytical data.

4.6.1 Focused SI Strategy

Surface water should be sampled if a release to surface water was suspected during the PA and surface water targets are present (e.g., drinking water intakes, fisheries, wetlands and other sensitive environments). Before identifying sample locations for the surface water pathway, the investigator must review the drainage pattern in the vicinity of the site. Water bodies that receive leachate or runoff from sources at the site should be sampled.

During the focused SI, the investigator should select sample locations near or immediately downstream of the site PPE to the nearest surface water body. Sampling effluent discharge into surface water at the PPE could document direct observation of hazardous substances contaminating surface water. In this case, background comparisons are not required.

The investigator should review surface water targets evaluated as primary targets during the PA. To investigate threats to public health, all drinking water intakes suspected to be contaminated should be sampled regardless of scoring impacts. For the drinking water threat, aqueous or sediment samples should be collected at or downstream of the intake suspected to be exposed to contamination. (However, only aqueous samples can establish Level I drinking water contamination). And if multiple targets are present downstream of the PPE, the protection of public health may indicate collecting at least one sediment sample at or beyond each target likely to be contaminated.

Samples to establish background must be the same type as the samples collected to test surface water release hypotheses or targets exposed to contamination. Background sample locations for the surface water pathway include:

- Sediments from the surface water body upstream from the PPE and outside the area of hazardous substance influence from the site

- Aqueous samples upstream from the PPE (only if drinking water intakes or sensitive environments are immediately downstream from the PPE)

4.6.2 Expanded and Single SI Strategy

Investigators should determine if analytical data from nearby surface waters are available. A minimum of two samples is needed to demonstrate a release:

- One upstream of the PPE to reflect background levels. It should be located within the same hydrologic setting as the downstream sample and, if possible, should not be influenced by other sources of potential contamination.

- One downstream reasonably close to the PPE.

If aqueous samples are planned, they should be collected prior to collecting sediment samples at the same location. In most cases, sediment samples are preferred to document a release to surface water because they are generally more likely to have concentrations significantly above background and they can support the evaluation of targets exposed to actual contamination. During the expanded SI, the investigator should consider collecting additional surface water samples for target locations not sampled during previous investigations. Expanding the boundaries of fishery contamination by collecting additional samples may be important if the human food chain threat has a major influence on the site score and if the waste characteristics factor category value is relatively low. Conversely, if the waste characteristic factor is relatively high, the boundaries of demonstrated contamination may not require expansion. Sampling to further document the extent of wetland contamination may also be warranted at some sites. Table 4-11 compares the focused and expanded SI strategies for surface water sampling.

4.6.3 Example of Sampling Strategy

Returning to the Lakefield Farm site example, the site description now includes the Apsley River, a moderate to large water body (streamflow 900 cubic feet/second), approximately 200 feet north of the surface impoundment (Figure 4-3). A recreational fishery is located within the river, and a 10-acre wetland lies 1 mile downstream from the PPE. An unnamed creek flows into Apsley about 750 feet upstream of the PPE, and an outfall to this creek is 1 mile upstream of this confluence. During the PA, the investigator suspected a release to the Apsley River from Lakefield Farm, and a release to ground water.

Because of significant threats to both ground water and surface water and because attribution is a problem, a focused SI is planned with an expanded SI to be performed if necessary. Focused SI sampling will test whether ground water and surface water targets are exposed to contamination.

If the number of samples to test all hypotheses exceeds the focused SI budget, a subset of these samples may be collected for the most important hypotheses to screen the site (Table 4-12). The previous ground water example specified 18 sample locations to meet focused SI objectives. To test surface water hypotheses, 5 additional sediment samples should be collected. A single sample from the municipal well (GW-7) or 3 samples from the river (SED-1, SED-4, and SED-5) may indicate whether further Superfund investigation is warranted.

Sediment samples may be collected from downstream wetland locations in addition to the 3 surface water samples identified above; however, these are not essential to test the suspected release to surface water. The SI investigator may perform other optional samples (e.g., a second background surface water sediment sample), and QA/QC samples (Q-1 through Q-4) consisting of 2 equipment rinsates, 1 trip blank, and 1 field blank.

Assume that focused SI ground water sample data do not detect hazardous substances at elevated concentrations. Fishery and wetland samples are contaminated with several heavy metals, and source samples from the surface impoundment at the site also contain some metals. Analytical results from the background samples were given "J" qualifiers and determined to be biased low. The investigator cannot conclusively determine whether the heavy metals found in the Apsley River are attributable to Lakefield

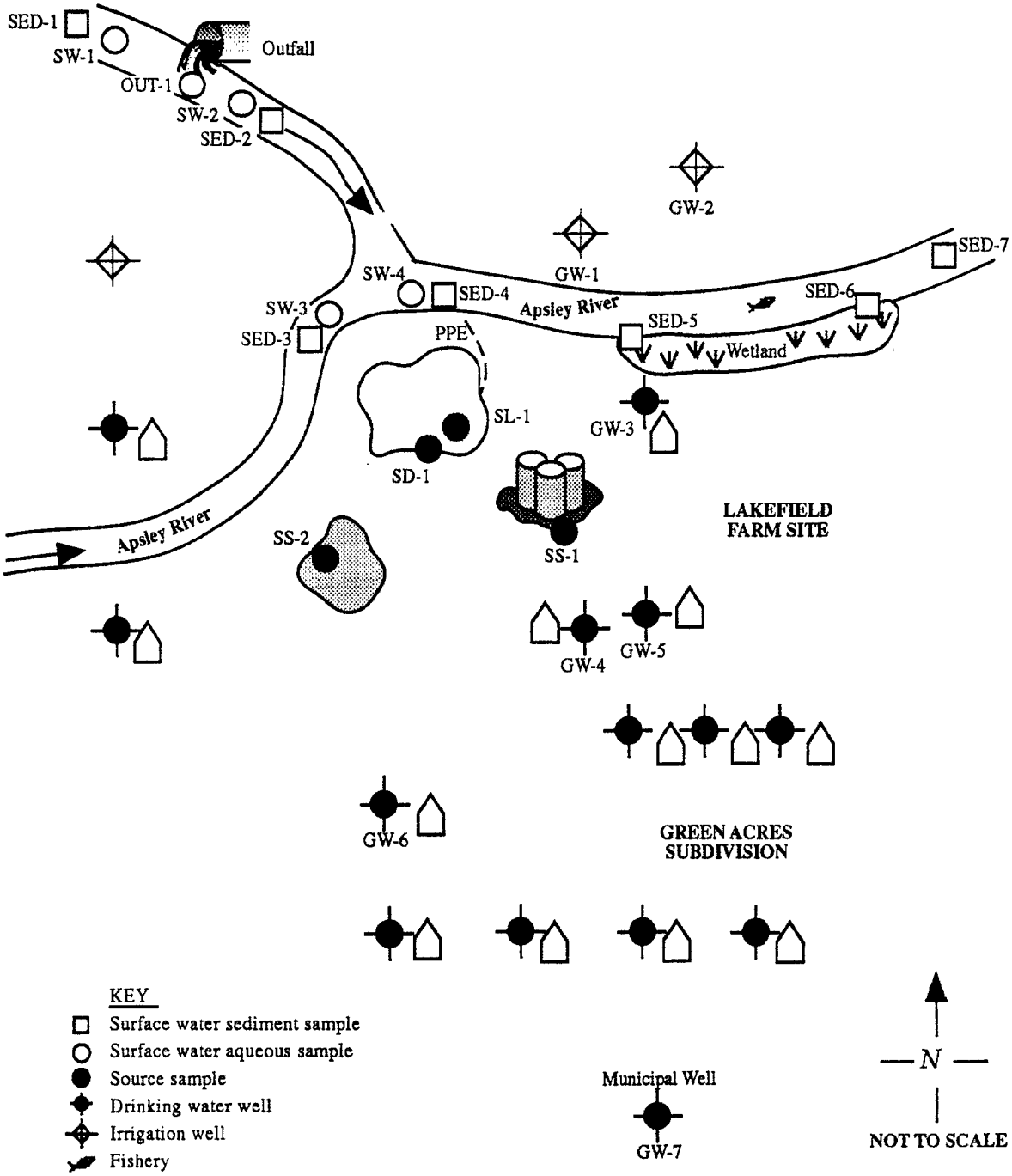
TABLE 4-11: SURFACE WATER SAMPLING STRATEGIES

CRITERION	FOCUSED SI	EXPANDED SI AND SINGLE SI
Primary objectives	To test hypotheses regarding a suspected release and primary targets When possible, sample at or beyond targets to test release hypotheses	To document a release based on HRS requirements To document targets exposed to actual contamination and determine levels of exposure
Data quality	Less rigorous (e.g., DUC-II) to rigorous (e.g., DUC-I)	Rigorous (e.g., DUC-I)
Average number of samples	0 to 6 depending on site hypotheses and number of surface water targets to sample	0 to 14 based on HRS documentation requirements
Types of activities	Sample easily accessible surface water locations Sample sediments at or beyond targets most likely to indicate contamination	Resample surface water locations if previous data did not document a release or targets exposed to actual contamination Sample surface water targets not yet sampled, particularly sensitive environments and wetlands Collect multiple aqueous samples from drinking water intakes where hazardous substance concentrations are likely to be near surface water benchmarks
Background samples	1 background per 3 release samples May rely on published data	2 background per 3 release samples Should not rely on published data
Attribution samples	Limited to testing release hypotheses	Those necessary to attribute a portion of a release to the site
QA/QC samples	Enhance confidence in sample results	Those necessary to obtain precise and accurate data within the SI scope

Farm, or whether they had entered the river through the outfall to the unnamed creek upstream of the site. A goal of expanded SI sampling will be to document that any significant increase in heavy metals concentrations found in the river are at least partially attributable to the site.

During the expanded SI, outfall discharge samples should be collected to determine if heavy metals are being released to the creek (OUT-1). Samples (SW-1 and SED-1) upstream of this discharge point should also be taken to determine if other sources (or sites) are releasing heavy metals to surface water. To further demonstrate actual wetland contamination, both aqueous and sediment samples should be collected further downstream along the wetland at locations likely to be exposed to a release from the site. The aqueous samples may demonstrate Level I

FIGURE 4-3: LAKEFIELD FARM SITE SKETCH #3



NOTE: Surface water aqueous and sediment sampling should begin downstream and progress upstream. In this example, sample SED-7 should be collected first, followed by SED-6 and so on upstream in reverse numerical order.

TABLE 4-12: SURFACE AND GROUND WATER SAMPLING STRATEGY FOR EXAMPLE SITE FOCUSED SI

SAMPLES	APPROACH	RATIONALE	NON-SAMPLING DATA COLLECTION
Municipal well (GW-7)	Sample drinking water prior to treatment; sample to document contamination, identify hazardous substances, and determine level of contamination	Determining municipal well contamination is critical to protecting public health and to the site screening decision	Verify aquifer from which well draws; verify population served
Domestic wells (GW-3 through GW-6)	Sample nearest domestic wells suspected to be exposed to actual contamination	Determining domestic well contamination is critical to protecting public health and to the site screening decision	Verify aquifer from which wells draw; verify population served
Background for ground water (GW-1, GW-2)	Sample drinking water aquifer; limit number of background samples	Sample to determine relative concentrations of hazardous substances in ambient conditions	Verify aquifer from which wells draw
Surface water target locations	Sample sediments to determine if contamination is present in the fishery (SED-4) or wetland (SED-5, SED-6)	Human food chain or sensitive environment contamination is vital to the screening decision	Verify linear footage of wetland exposed to actual contamination
Background for surface water (SW-1, SED-1)	Limit number of background samples	Sample to determine levels of hazardous substances	Collect information about background sample location including setting, flow, and physical characteristics (e.g., Sediment grain size)
Sources (SD-1, SL-1, SS-1, SS-2)	Identify hazardous substances present at the site through composite samples	Do not sample to increase hazardous waste quantity if amounts are not close to HWQ factor value breakpoints	Obtain physical dimensions of surface impoundment and estimate area of contaminated soil; verify number of drums and look for drum labels
Quality control (Q-1 through Q-4) (Not shown)	Monitor collection and decontamination procedures; 1 rinsate for ground water equipment, 1 rinsate for surface water equipment, 1 trip and 1 field blank		

contamination for the wetland, the sediment samples may demonstrate Level II. (The wetland sample locations should be at least 0.1 mile apart, the minimum frontage length needed to receive a non-zero factor value.)

Other background samples should be collected from the Apsley River upstream of the confluence with the unnamed creek. Samples from within the fishery should be taken to compare to background and attribution samples. Also, QA/QC samples should be collected following EPA Regional guidance. For this expanded SI example, 2 equipment rinsates, 1 trip blank, 1 duplicate, and 1 blank could monitor sample collection and handling procedures (Table 4-13).

4.7 SOIL EXPOSURE PATHWAY

The primary objective of soil exposure sampling is to identify whether residential or school properties are contaminated. Sample locations for the soil exposure pathway should:

- Document any observed contamination within property boundaries of a residence, shcool, day care center, or workplace, or within the boundaries of a terrestrial sensitive environment or resource;
- Document observed contamination significantly above background levels and attributable to the site;

TABLE 4-13: SURFACE WATER SAMPLING STRATEGY FOR EXAMPLE SITE EXPANDED SI AND SINGLE SI

SAMPLE	APPROACH	RATIONALE	NON-SAMPLING DATA
Surface water locations	Sample sediments and surface waters to confirm contamination of surface water targets, levels of actual wetland contamination, linear frontage of wetlands exposed to actual contamination, and attribution to the site	Target samples should be comparable to background samples collected If necessary, wetland sample locations should be selected to demonstrate that at least 3 miles of linear frontage are exposed to actual contamination	Measure linear frontage of wetland exposed to actual contamination
Background and attribution (SW-1, SED-1, SW-2, SED-2, OUT-1)	Sample to determine if outfall or another source upstream may be contributing to surface water contamination	Sample to determine relative levels of hazardous substances in ambient environment Show contamination attributable to site Ensure sufficient background samples for listing documentation	Research other potential sources (e.g., industrial areas) Collect information about background sample location
Quality control (QA-1 through QA-5)	Monitor sample collection, decontamination, transport, and handling procedures; 2 equipment rinsates, 1 trip blank, 1 duplicate, and 1 field blank	Ensure sufficient QA/QC samples to validate sampling and analytical procedures	

- Delineate areas of surficial contamination at the site; and
- Identify the level of contamination within these areas.

Samples, including composite samples, must be collected within 2 feet of the surface. No impenetrable material (e.g., asphalt, concrete) should be present above the sample location. Most surface samples during the SI will be soil material, although some may be leachate, source material, sediment from overland runoff drainage ditches, and other surficial materials. Certain conditions are imposed on establishing observed contamination at a sample location. Similar to an observed release, analytical evidence should demonstrate whether the hazardous substance is attributable to the site and present at a concentration significantly above background levels. If no surficial contamination significantly above background levels and attributable to the site is detected, the soil exposure pathway cannot be evaluated.

Areas of observed contamination are delineated based on analytical evidence meeting the criteria for observed contamination. Observed contamination in the soil exposure pathway cannot be established by direct observation. Samples that contain hazardous substance concentrations significantly above background and are attributable to the site are used to document points of observed contamination. The most important analytical data for the soil exposure pathway are samples that establish observed contamination and level of contamination.

Documenting resident population targets requires detecting contamination (most commonly in soil) within the property boundary, within 2 feet of the surface on the property and within 200 feet of residences, schools, day care centers, or workplaces. The SI investigator should identify and sample routes through which hazardous substances may be transported by air or water. Physical site characteristics and background information, especially aerial photography, may help identify potential former disposal areas that are close to, or part of, residential properties.

The investigator should sample surface materials based strictly on identifying resident population threat targets. A minimum of three samples is necessary to estimate the area of observed contamination. Two samples may be sufficient to define a linear strip of contaminated soil, where targets within the strip are critical to the site score and area is not important. If a large number of residences (e.g., mobile home park, residential development on a landfill) are likely to lie within an area of contamination, estimating the boundaries of contamination, particularly during the focused SI, may be more practical. The expanded SI would include samples to distinguish levels of contamination within this area.

For sources other than contaminated soil (e.g., a surface impoundment), a single source sample demonstrating observed contamination may be used to identify the entire source as an area of observed contamination. Any sample establishing hazardous substance concentrations significantly above background levels indicates the source area is an area where observed contamination is greater than 0. Thus, one point of known contamination may provide sufficient information for scoring. For contaminated soil, locations of samples that demonstrate observed contamination and the area between those locations comprise the area of observed contamination, unless information indicates otherwise.

To evaluate the level of contamination for each residential, day care, or school property, each area of observed contamination should be delineated according to concentration levels relative to benchmarks. For HRS scoring purposes, contamination can be inferred between 2 points of observed contamination based on site conditions; however, the population associated with the areas of inferred contamination are evaluated as Level II resident threat targets. The investigator should identify areas where observed contamination can and cannot be inferred. For decision-making purposes, the investigator may use analytical evidence with nonsampling evidence to infer or corroborate the area of observed contamination-for example, observation of stained soil coupled with analytical results from the stain. Other corroborative information may be:

- Data derived from other investigations, such as geophysical or soil-gas surveys;
- Documented historical waste deposition patterns
- Patterns of stressed vegetation;
- Infrared satellite imagery indicating soil anomalies; and

- Topography and drainage patterns.

If samples not meeting the criteria for observed contamination are collected from within an area of inferred contamination, the investigator should evaluate whether the area of contamination needs to be refined or modified. For example, if liquid wastes containing hazardous substances were spilled at the site, areas of higher elevation than the spill generally should be excluded from the area of inferred contamination, even if they are within the originally inferred area. However, the scope of the SI generally does not warrant fully delineating areas that are not subject to observed contamination; instead, the primary objective is to identify targets that may be threatened by the site.

Special precautions should be taken to ensure the sample represents the surface at that location, and that the sample is not altered or contaminated by sampling and handling procedures. Soil samples collected for comparison should be the same soil type and from the same soil horizon. Considerable variability may occur between soil types as well as within a single soil type because of grain size, mineralogy, composition, soil horizons, and lateral heterogeneity. Soil type should be identified and delineated. For metals analysis, background, and observed contamination, soils should have similar texture, color, and grain size.

For general HRS purposes, grab samples are better than composite samples for the soil pathway. Where composite samples are needed, the SI investigator should avoid mixing soils from different properties. Also, all portions of the composite sample should be taken within 200 feet of the school or residence on the property.

Background samples generally should represent the uncontaminated area around the site. Background samples should be collected from undisturbed areas if the site is located near areas filled in with soils from different sources. However, if the site is located in fill material, the background sample should come from the fill. Soil within drainage channels (e.g., overland migration segments) may be subject to influences unrelated to the site and generally should not be used as background. Background and observed contamination samples should be collected within a reasonable time (1 to 3 days).

Data resulting from field screening methods may be useful to investigate source boundaries and areas of contamination. For example, if soil samples need to be collected from adjacent residences or schools to investigate resident population targets, field screening can help plan the locations of samples to be collected for CLP analysis. Field screening samples may support evaluation of observed contamination and reduce the number of CLP samples necessary to document the pathway score.

Establishing background conditions for the soil exposure pathway can be difficult, particularly when the hazardous substances found at the site are naturally occurring. Onsite samples to establish background should be collected from off-source surficial soils that are not likely to be impacted by the source. Similarly, the SI investigator should collect offsite samples to establish background conditions from shallow soils that are not impacted by other sources in the vicinity.

Results from other nearby site investigations can be used during the focused Sl to establish background. Literature values, especially for naturally occurring substances such as metals in mining areas, may be used as background measures during the focused SI.

4.7.1 Focused SI Strategy vs. Expanded and Single SI Strategy

To plan target sample locations, the investigator should review PA conclusions of resident population targets suspected of exposure to contamination. Samples collected from a terrestrial sensitive environment must be within the delineated boundaries of the specific sensitive environment. To investigate the threat to workers at the site or at adjacent properties, samples must be collected on the facility property within 200 feet of the workplace.

For the expanded SI, the investigator only should use data of rigorous quality to support target exposure. Less rigorous data and non-sampling information may corroborate attribution and representativeness of samples.

One or more background samples to compare to observed contamination areas are necessary to document contamination. Background samples should not be influenced by other potential sources of contamination. Generally, samples taken at a higher elevation than site sources can be used as background, unless the hazardous substances can be transported by wind. For all background sample locations, care should be taken to ensure that they are not affected by substances blown from the site.

Careful selection of background sample locations is important since any measurable concentrations of specific substances found at residences, schools, day care centers, workplaces, and terrestrial sensitive environments will be compared to background data. If several of these properties are present, observed contamination may be inferred between two points of observed contamination based on terrain, drainage, surficial runoff, elevation, and other site conditions unless available information indicates otherwise. However, populations associated with inferred contaminated properties cannot be scored as Level I resident threat targets. Sampling each property is not necessary, although documentation will be stronger if each property is sampled. Table 4-14 compares focused and expanded SI strategies for the soil exposure pathway.

TABLE 4-14: SOIL SAMPLING STRATEGIES

CRITERIA	FOCUSED SI	EXPANDED SI AND SINGLE SI
Primary objectives	To test hypotheses regarding suspected observed surficial contamination and targets exposed to actual contamination	To document target exposure to hazardous substances related to site sources
Data quality	Less rigorous (DUC-II) to rigorous (DUC-I); depends on objectives	Rigorous (DUC-I); depends on objectives
Average number of samples	0 to 10 depending on site hypotheses and resident population to investigate	0 to 20 based on documentation requirements and number of sources and targets
Types of activities	Sample source and target areas indicating possible surficial contamination, exposed or within 2 feet of surface	Resample locations if previous data did not demonstrate areas of observed contamination or targets exposed to actual contamination Sample other resident target properties not yet sampled Collect multiple samples from properties where hazardous substance concentrations are likely to be near benchmarks
Background samples	Limited May not be necessary for some organics May rely on published data	As many as necessary; research natural soil concentrations as well as development history in the area to select critical background sample locations; use aerial photographs.
Attribution samples	Limited	Those necessary to attribute substances to the site being evaluated
QA/QC samples	As approved by Regional guidelines	Minimum 1 split and 1 blank or per Regional guidelines

4.7.2 Example of Sampling Strategy

The Carveth Landing Site is a dump near a residential neighborhood and elementary school (Figure 4-4). The PA reported that dumping occurred for an unknown period of time and allegedly included paints, organic and inorganic substances, and construction debris. The area is devoid of vegetation. Sources at the site include several piles of 5-gallon containers and two poorly defined areas of stained soil. Pigeon River, which flows at 1600 cubic feet per second (cfs) and is located 400 feet east of the site, has flooded the site twice in the past 7 years. Commercial and recreational oyster beds are downstream of two PPEs to surface water. The PA concluded that flooding may have carried hazardous substances into surface water and onto adjacent school and residential properties. Hazardous substances associated with the site are not known, but could involve metals typically found in paints.

A two-stage SI was planned for Carveth Landing because testing critical PA hypotheses could screen the site or identify significant threats. Sample planning involved the following considerations: 1) surface water and soil exposure are both pathways of concern; 2) hazardous substances present at the site are poorly-defined, some of which may be naturally occurring; and 3) source information is poor. Focused SI samples were collected to test the suspected release to Pigeon River, identify the hazardous substances present, and determine whether any suspected resident population threat target is exposed to actual contamination.

During the focused SI, soil source samples were collected to identify hazardous substances: two samples from each stained soil area and two samples near the container piles (SS-1 through SS-6). These samples also helped characterize areas of surficial contamination and attribute possible contamination of residential properties to site sources. Samples were collected from properties most likely to exhibit surficial contamination. A significant objective was to demonstrate contamination on the school property. During the focused SI, samples (SS-1 and SS-2) were collected from the school and from the three nearest residential properties all within 200 feet of the residences and school building. Two background soil samples (SS-7 and SS-8) were collected 12 inches below the surface in offsite soils.

Establishing a release by direct observation was considered for the surface water pathway; however, the available site information could not conclusively demonstrate that material containing hazardous substances was present at the site during flooding. Therefore, focused SI sampling included two sediment samples (SED-3 and SED-4) from locations where overland runoff from site sources entered surface water (i.e., PPEs) to test a suspected release to Pigeon River and actual human food chain contamination. Background surface water sediment samples (SED-1 and SED-2) were collected near the right and left banks of Pigeon River, 200 and 800 feet upstream of the most upstream PPE into Pigeon River. QA/QC samples consist of two equipment rinsates (1 for sediment and I for soil) and a field blank (Table 415).

Although lead concentrations in this focused SI example are above soil exposure pathway benchmarks, the concentrations are not significantly above background soil levels. For this example, the background samples were inadvertently taken within an area of soil contaminated by automobile emissions, floods, wind-blown wastes, or naturally high lead concentrations.

The expanded SI includes 2 additional source samples (XS-1 and XS-2) and more soil samples to document observed contamination at the site, on the properties sampled during the focused SI, and on other residential properties potentially affected by the site (Table 4-16). Background sod lead concentrations should be researched by literature values and additional background samples (XS-3 through XS-6 and XS-10) collected at locations less influenced by potential sources of lead contamination. Soil samples from residential properties southeast of the site should also be taken since they are closer to the river. In addition, samples from targets previously sampled during the focused SI should be taken if background samples collected during the focused SI are not similar to the additional target samples.

FIGURE 4-4: CARVETH LANDING SITE SKETCH

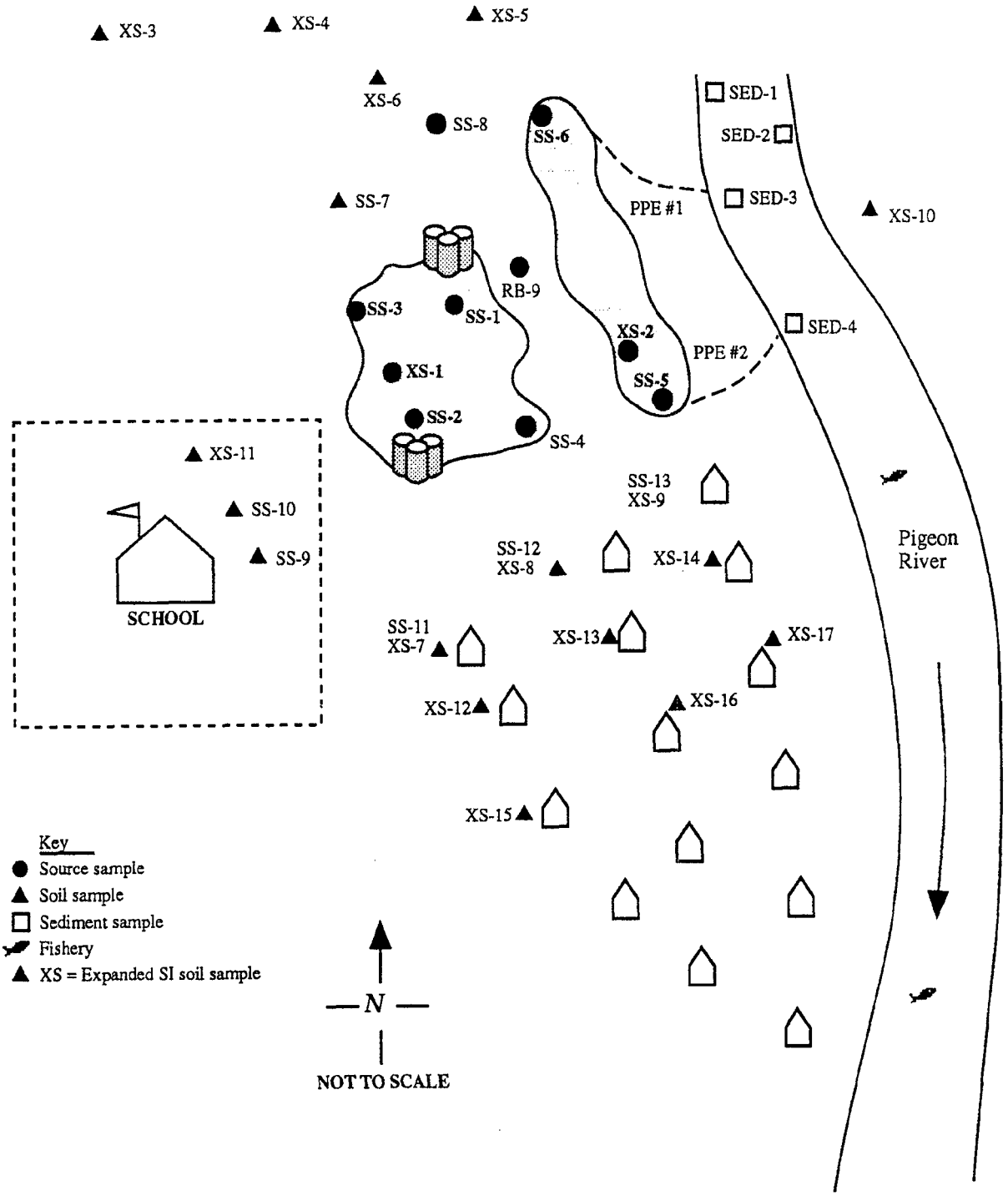


TABLE 4-15: SOIL AND SURFACE WATER SAMPLING STRATEGY FOR EXAMPLE SITE FOCUSED SI

SAMPLES	APPROACH	RATIONALE	NON-SAMPLING DATA
Surface water locations (SED-3, SED-4)	Sample sediments to demonstrate a release; determine if contamination is present and level of contamination	Investigate release to surface water and determine if fishery is exposed to actual contamination	Document use of river for fishing; estimate annual commercial food chain production for oysters
Residential soil samples	Sample to determine if nearby residential properties (SS-11, SS-12, SS-13) and the school yard (SS-9, SS-10) are exposed to surficial contamination	Investigate population exposure to hazardous substances	Determine number of people per residence and number of students attending school
Background soil (SS-7, SS-8)	Limited	Sample to determine relative levels of hazardous substances under ambient conditions and to better define effects of flooding at site	If available, obtain historical aerial photographs and FEMA maps Research natural background levels of metals
Background surface water (SED-1, SED-2)	Collect sediment samples upstream of PPEs Ensure samples are beyond tidal influence of hazardous substance migration	Sample to determine relative levels of hazardous substances under ambient conditions	Research other potential sources of hazardous substances
Sources (SS-1 through SS-6)	Identify hazardous substances present at the site; sample to test hypothesis of surficial contamination	Do not sample to increase hazardous waste quantity because amounts are not close to HWQ factor value breakpoints	Estimate physical dimensions of stained soil; count paint pails and look for drum labels
Quality control (Q-1 through Q-3)	Monitor sample collection and decontamination procedures; 2 rinsates and 1 trip blank		

TABLE 4-16: SOIL SAMPLING STRATEGY FOR EXAMPLE SITE EXPANDED SI

SAMPLES	APPROACH	RATIONALE	NON-SAMPLING DATA
Resident samples (XS-7, XS-8, XS-9, XS-11 through XS-17) 10 samples	Sample to document resident targets and levels of actual contamination	To establish observed contamination on residential and school properties, target samples must be 3 or more times the ambient background levels	Determine number of residents, property boundaries, and number of students
Background (XS-3 through XS-6, XS-10)	Sample area less influenced by site; document contamination attributable to site	Show that target contamination is attributable to the site, rather than other potential sources of lead; ensure sufficient background samples for HRS documentation	
Quality Control (Q-1 through Q-6)	Monitor sample collection and decontamination procedures; transport and handling procedures; 2 equipment rinsates, 2 duplicates, 1 field blank, 1replicate	Ensure sufficient QA/QC samples for HRS documentation	

Expanded SI QA/QC samples for this example (Q-1 through Q-6) include 2 equipment rinsates, 2 duplicates, 1 field blank and a replicate sample at the site owner's request.

4.8 AIR PATHWAY

Generally, air sampling is an, expanded SI activity. If suspected air pathway contamination hypothesized during the PA or focused SI is solely responsible for further investigation (i.e., all other pathways have minimal effect on scoring), air samples should be collected during a single or an expanded SI. Formal air sampling to document a release is limited to the single or expanded SI unless there is concern about an immediate threat to human health.

The SI air sampling strategy requires understanding the types of hazardous substances associated with the site. The most dispersible substances should be identified. Air sampling should be conducted either before, or after all other sampling activities (i.e., not during field activities that may release substances to the air). Air sampling may require returning to the site, for example, on a dry warm day when the potential for volatilization is high. Air sampling should be avoided if the site or nearby facilities are discharging substances to the atmosphere.

Hazardous substances can be released into the atmosphere by wind, fire, explosion, evaporation, sublimation, and industrial processes. Defining the likely path and dispersion of a release to air requires information on release characteristics and atmospheric conditions. Emissions of contaminated fugitive dusts (e.g., contaminated soil particles) originating from a source can result from a combination of factors at the site, such as wind erosion, heavy equipment or vehicular traffic, and incineration. The likelihood of a release to air also depends on the type of source

containing hazardous substances, the chemical properties of these substances, and the thickness of cover at the source.

An observed release to air may be documented through direct observation. An example is observation of particulate matter entering the atmosphere directly and information indicating the material contains one or more hazardous substances. In this case, a photograph referenced in the field logbook may be adequate to document direct observation (e.g., a dust cloud from a tailings pile). A sample of particulate material from the pile detecting hazardous substances strengthens the documentation of the release by direct observation.

Unlike other pathways, direct sampling of air targets suspected to be exposed to contamination is not required; an air observed release allows any person regularly present or any sensitive environment within the distance category, or a closer one, to be evaluated as subject to actual contamination. Investigators should note the distance from sources at the site to air sample locations. Monitoring stations should be placed near source areas to maximize the use of data in HRS air target evaluations. A release into the air of an enclosed structure is not considered an observed release.

Samples should be representative of the location and not be altered by sampling and handling procedures. Background air samples and samples establishing an observed release should be collected in a similar setting and at the same time. Background samples should be outside the influence of sources to ensure that hazardous substances detected in release samples are attributable to the site.

4.8.1 Focused Sl Strategy-Air Pathway

Air sampling for CLP analysis should not be conducted during the focused SI. However, an ambient air "screening" program may be warranted for health and safety monitoring and to initially assess a release. This program should examine specific hazardous substances with a high propensity for a release (e.g., VOCs). However, data collected during the screening program typically do not fulfill HRS documentation requirements.

For the focused SI, the investigator should review the results from the PA and other investigations. For sites with several pathways of concern, field instruments such as an OVA or HNu should be used to refine the evaluation of a suspected release to air. Readings above background in a zone near undisturbed source areas, or particulate matter observed migrating from source areas, could be used to evaluate an observed release to air during the focused SI. Further investigation during the expanded SI would pursue documenting the release. If the air pathway scored greater than 57 during the PA and is the only pathway responsible for the further action recommendation, the single SI option is appropriate.

For VOCs, the screening program could include an initial survey using portable instruments designed to provide a field-expedient measure of total VOCs. The initial survey locates and delineates potential emission sources for formal air sampling during the expanded SI. During the focused SI, field screening methods— for example, collecting air samples with a field gas chromatograph equipped with a photoionization detector—may be useful.

4.8.2 Expanded and Single SI Strategy— Air Pathway

Air sampling may be appropriate during the expanded SI if air is a pathway of concern or if public health is threatened in the vicinity of the site. Investigators should review the likelihood of atmospheric releases (gases and particulates) from site sources. Of all HRS pathway media, air may be most dependent on weather, particularly wind speed and direction, temperature, and relative humidity. A minimum 12-hour sampling time is recommended during hot and dry weather to compensate for possible variations in these factors over time.

The predominant wind direction should be determined throughout the time period of sampling. Air should generally be sampled upwind of sources for background measures. Formal air sampling during a single SI should include a complete set of background samples because of the level of effort involved in an air sampling program. This differs from the guidelines for other pathways. Air should be sampled downwind of sources to investigate a release. Up

wind and cross-wind samples may also be acceptable for background. Multiple background and target samples should always be considered. Background and observed release samples should be taken at the same time from approximately the same heights above the ground. Samples collected at great heights (e.g., rooftops) are not useful. Samples from very low heights are also not encouraged because field activities, particularly surface disturbance, may introduce artificial contamination. In general, dust or wipe samples are not recommended to establish a release to air. Analytical results from these samples are not usable to document a release to air for HRS scoring package purposes.

Soil samples may not qualify to document an observed air release by chemical analysis since substances may have migrated via non-atmospheric transport mechanisms. Soil-gas surveys, although sometimes useful in determining the placement of air monitoring stations, do not provide the quality of data needed to document an observed release to air. Although methane may support a release of other hazardous substances from a source, methane cannot be used as the observed release substance because it is not a designated hazardous substance under CERCLA Section 101(14). In addition, methane alone (which can occur naturally) does not indicate that hazardous substances are present or migrating from a site.

For sites where several pathways are of concern, field instruments such as an OVA or HNu should be used to refine the evaluation of a release to air. Readings above background near undisturbed source areas or particulate matter observed migrating from source areas should be documented during the expanded SI.

4.8.3 Example of Air Sampling Strategy

Vega Ore is a remote site near Smalltown where ore is processed for the extraction of lead, zinc, and silver (Figure 4-5). The site has been operating since 1930, and current activities are very limited. Waste sources include three tailings piles, a drum storage area for acids, and an aboveground tank.

The nearest residence is 1000 feet from a tailings pile. Smalltown relies on drinking water from an intake 3 miles away. A National Park is located 900 feet from the site. A total of six ranches within 0.25 mile of the site rely on both bottled water and cisterns for drinking water. Based on PA research, the significant threats posed by Vega Ore involve suspected migration of hazardous substances through air that may impact people and sensitive environments. No ground water targets exist, and the nearest surface water body is more than two miles from the site. Because only the air pathway significantly affects the example site score, a single SI is planned for Vega Ore to investigate a release to air and targets exposed to actual air contamination within the 0.25-mile target distance category. Table 4-17 summarizes a suggested air sampling strategy for Vega Ore. Air samples to demonstrate targets exposed to actual contamination should be collected at locations outside source boundaries. These locations should be within the boundaries of the National Park and the other areas within the 0.25-mile radius.

Soil samples from sources should be collected to help attribute hazardous substances found in the release samples to Vega Ore. Five source samples (SS-1 through SS-5) should be taken, including 1 sample from each tailings pile, 1 from soils in the drum storage area, and 1 from soils near the above-ground tank. Air sampling should be designed to collect particulates since the largest quantities of hazardous substances associated with the site (i.e., lead, zinc, silver) do not typically exist as gases in the environment. Sampling should occur when the prevailing easterly winds are steady and other weather conditions are suitable. Wind speed and direction, air temperature, and other atmospheric characteristics should be continuously monitored and noted in the logbook.

All air samples should be taken during the same time period, and sample collection should run for at least 12 hours (air samples to establish Level I contamination for lead must be collected over a 24 hour period). A high-flow pump may be used to collect both background and release samples through a filter cartridge. Air sample stations should be placed both upwind (A-1 through A-3) and downwind (A-4 through A-8) of site sources. Cross-wind

FIGURE 4-5: VEGA ORE SITE SKETCH

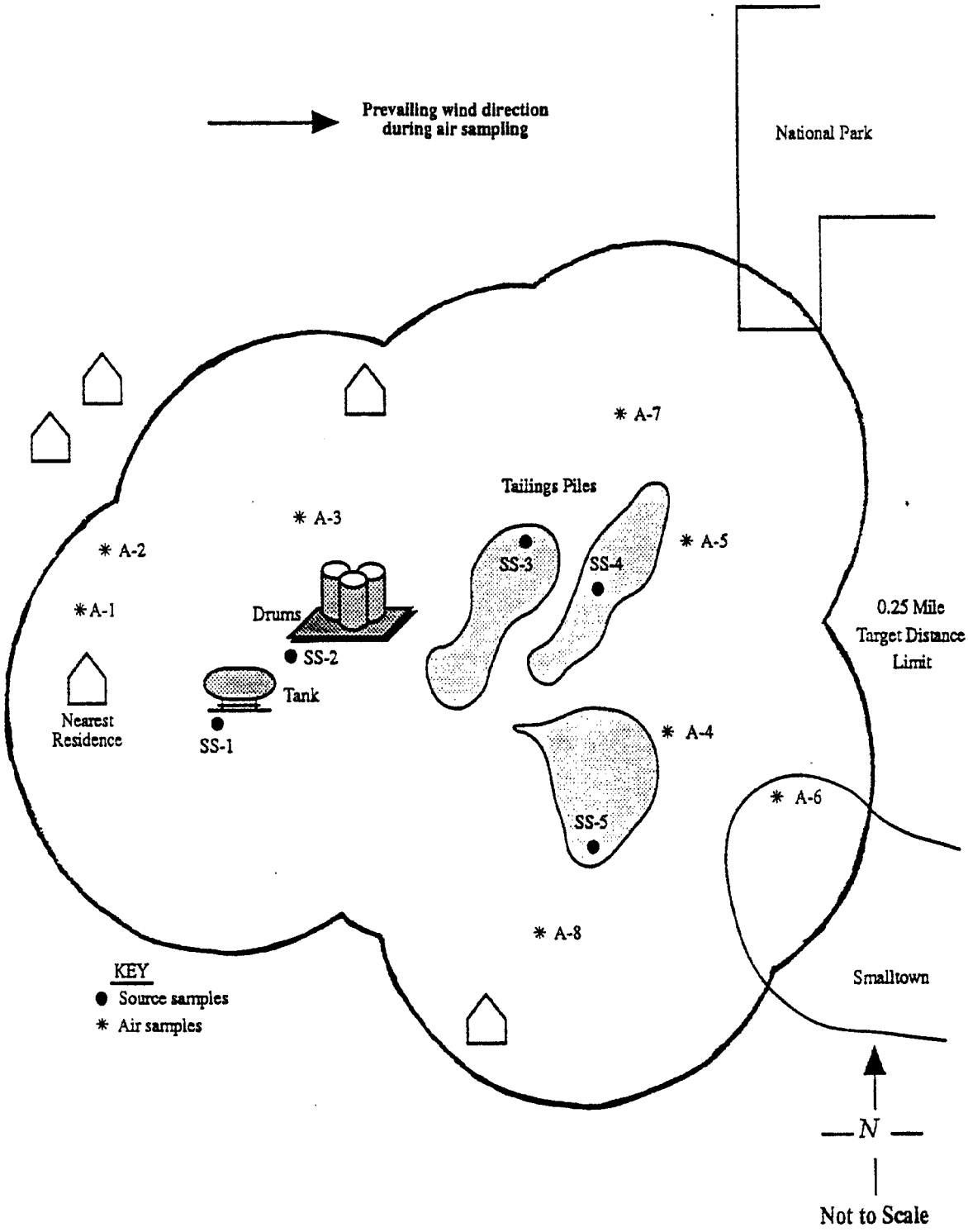


TABLE 4-17: AIR SAMPLING STRATEGY FOR EXAMPLE SITE SINGLE SI

SAMPLES	APPROACH	RATIONALE	NON-SAMPLING DATA
Release and Air Targets (A-4 through A-6)	Sample to test if contamination is present and determined level of actual contamination Monitor wind speed, direction, and other atmospheric conditions	Determining whether the 0.25-mile target distance category is exposed to actual air contamination is vital to investigating the public health and the screening and listing decisions	Determine population of Smalltown lying within the 0.25-mile target distance category from site sources Determine number of workers at Vega Ore Determine boundaries of National Park
Support for Release and Air Targets (A-7, A-8)	Sample to test if other sources of air contamination exist in the site vicinity, or if wind direction changes during the sampling event; establish cross-wind sample stations	Support determining whether the 0.25-mile target distance category is exposed to actual air contamination	
Background (A-1 through A-3)	Sample to collect background levels of ambient air concentrations Sample to determine background soil levels	Sample to determine relative levels of particulate hazardous substances in ambient conditions Ensure sufficient background sample for listing purposes	Identify other sources of particulate emissions in area Collect descriptive information for all background sample locations
Sources (SS-1 through SS-5)	Identify hazardous substances present at the site through surficial soil samples and tailing samples	Do not sample to increase hazardous waste quantity (amounts are not close to HWQ factor value breakpoints)	Obtain physical dimensions of tanks, drums, and tailings piles, and estimate area of contaminated soil; verify number of drums and look for drum labels
Quality control (Q-1 through Q-4) Not shown)	Monitor sample collection and decontamination procedures; 2 trip blanks and 2 duplicates	Ensure sufficient QA/QC samples for listing purposes	

sample stations may be appropriate depending on atmospheric, weather, and site characteristics, and the potential for other sources of air contamination to contribute to particulate concentrations. QA/QC samples (Q-1 through Q-4) could include 2 trip blanks (i.e., the sampling event will take 2 days) and 2 duplicates. A field blank is not normally required.

For specific procedures on air sampling, refer to the National Institute for Occupational Safety and Health (NIOSH) *Manual of Analytical Methods*, Volumes 1-7, and EPA's *A Compendium of Superfund Field Methods*.

4.9 SITES WITH RADIOACTIVE WASTES

This section provides guidance for performing SIs at sites with wastes containing radioactive substances. For field investigations of sites with radioactive wastes, the SI investigator should refer to EPA's *Radiochemical Procedures Manual* (1984) and the Department of Energy's *EML Procedures Manual* (1983). The SI investigator should also consult the EPA Regional, laboratory, or Headquarters Radiation Programs staff. In addition, the following references provide useful information:

- National Council on Radiation Protection and Measurements, 1976. *Environmental Radiation Measurements*, NCRP Report No. 50

- U.S. EPA, 1979, *Radiochemical Analytical Procedures For Analysis of Environmental Samples*. EMSL-LV-0539-17

- U.S. Nuclear Regulatory Commission, *Radiological Assessment: A Textbook on Environmental Dose Analysis*. NUREG/CR-3332. Till and Meyers (Eds.).

Sampling strategies for sites with wastes containing radioactive substances are similar to those described in previous sections for other hazardous substances, but with some important differences. These differences can be attributed, in part, to:

- Higher specificity and sensitivity of procedures used to detect radionuclides in the environment; and

- Special data requirements for scoring radiation sites under the HRS.

The SI investigator should be aware of special precautions in sampling, handling, and disposing of radioactive materials, and should work with an EPA health physicist or radiochemist in planning the sampling strategy.

4.9.1 General Sampling Principles

In general, sampling strategies for sites with only radioactive substances are less complex than strategies for sites with other hazardous substances. The sensitivities, specificities, and instantaneous readout capabilities of many field instruments facilitate investigating sources and releases of radioactive substances. Field identification and monitoring of specific radionuclides, source locations, release points and distances to targets can be used to focus sampling efforts and reduce the number of samples required for scoring. In addition, real-time radiation measurements allow modification to the sample plan, alert site personnel of unsafe radiation exposure levels, and permit the monitoring of collection and decontamination procedures.

Prior to developing the SI sample plan, the SI investigator should review PA and previous sampling data regarding sources and pathways with known or suspected radioactive substances to plan samples. Also, early in the SI planning process, the investigator should review section 7 of the HRS and be familiar with the data requirements of radionuclide-specific factors that require special sampling. For example, calculations of factor values for radionuclide benchmarks and hazardous waste quantity require that measurements be reported in activity units rather than mass units.

The investigator should review available site data to identify potential radionuclides. Data sources can include records of the site operating history, handling and disposal manifests, radioactive materials licenses issued by the Nuclear Regulatory Commission (NRC) or through State agreement, and previous sampling and analysis. Interviews with former employees can also provide useful information on site operations. The investigator should use these records to construct an initial list that contains the following data for each radionuclide:

- Atomic number and atomic weight
- Radioactive half-life
- Principal decay modes and radiation energies and abundances
- Chemical and physical forms
- Decay products

Half-life information is critical to determine persistence factor values and the degree of activity equilibrium between decay products. Half-life also affects holding times for analyses.

The type (alpha, beta, gamma photons and x-rays), abundance, and energies of the radiation emitted by a radionuclide are unique. Sampling and analysis procedures, radioanalytical methods, and radiation-detection instruments must be consistent with the decay mode and radiation energies and abundances of the radionuclide.

Bioaccumulation potential and metabolic behavior of a radioisotope are governed by its chemical and physical form, not by its radioactive properties. The toxicity of a radioisotope depends on its radioactive properties. Since radionuclides may be released to the environment as solids, liquids, or gases in a variety of chemical forms, oxidation states, and complexes, information on the most likely chemical and physical form of each radionuclide at the time of production, disposal, release, and measurement is important for developing initial sampling strategies.

Radioactive decay of an isotope of one element may result in the formation of an isotope of a different element or a different isotope of the same element. Resulting decay products have physical and chemical properties different from the parent radionuclide. Often, a decay product is also radioactive and decays to form another radioactive substance. Decay products should be considered on a substance- and site-specific basis in the evaluation of factor values for radionuclide toxicity, hazardous waste quantity, and mobility and persistence because:

- Total activity content and potential hazard of a sample may be underestimated if decay products are not included;
- Decay products may be more toxic, either alone or in combination, than the parent radionuclide; and
- Environmental transport, fate, and bioaccumulation characteristics of decay products may be substantially different from those of the parent radionuclide.

In selecting detection instruments and procedures, the SI investigator should consider the following conditions for each radionuclide in each media sample:

- Type, abundance, and energy of radiation emitted by radionuclides of concern
- Expected activity concentrations of radionuclides in sources and environmental media
- Background concentration
- Turnaround time for analyses
- Required analytical sensitivity
- Data requirements for specific HRS factors

The SI investigator should schedule analyses with laboratories that can provide radioanalytical services through the CLP SAS or a CLP-equivalent program. The investigator must specify radiochemical methods and QC test requirements. These should be compared with the lists of procedures for radionuclides, matrices, detection limits and sample collection, preservation, holding times, and shipping requirements supplied by each candidate laboratory. The investigator should review the radioactive materials license and conditions of each sampling laboratory to ensure that the laboratory can accept the samples for analysis.

Focused SI Sampling Principles

Similar to other sites, the focused SI at radiation sites uses analytical data to test PA hypotheses and to recommend the site for further evaluations. However, the focused SIs sampling strategy to investigate radioactive substances relies more heavily on field instruments and methods to:

- Locate elevated sources of radioactivity and external radiation exposure rates;
- Determine the identities and activity concentrations of radionuclides *in situ*;
- Estimate areal extent of contamination;
- Identify major migration pathways;
- Confirm releases; and
- Confirm offsite contamination.

EXAMPLE OF A FOCUSED SI SAMPLING STRATEGY AT A RADIATION SITE

From 1910 until 1952, the ACD Corporation produced luminescent aircraft cockpit dials using radium-based paint. The area immediately surrounding the ACD factory supports a residential population of about 18,000. Historical records indicate that the factory received substantial quantities of unprocessed radium ores during its years of operation. These ores were unloaded at a bay adjacent to railroad tracks. The abandoned factory grounds cover about 20,000 square feet and the property is accessible to the public due to a broken security fence.

A review of available records suggested that processed radium ores were discarded at the factory. The PA site visit confirmed the presence of several large piles of processed radium ore and smaller amounts of unprocessed radium ore discarded along the railroad tracks. A drinking water aquifer lies approximately 30 feet below the site.

The SI investigator conducted a walk-over gamma radiation survey of the site and collected a limited number of samples to test the PA hypotheses that site sources and soils on adjacent residential properties contained elevated levels of radium. The investigator identified Ra-226 and its decay products as the primary radionuclides of concern and assumed that these radionuclides were present in equal activity concentrations. Background samples were not collected, but natural activity concentrations for radium in soil, water, and air were noted from scientific reports for the surrounding region.

Survey measurements identified at least 17 source waste piles with gamma radiation exposure rates significantly above background levels. The soil on four residential properties adjacent to the site also showed significant exposure rate readings. Four surface soil samples were collected: one from an ore pile on the factory grounds and the others from the front yards of three of the homes. Every sample contained highly elevated radium concentrations. Results of the single ground water well sample (900 feet from the site) were negative. Based on these documented levels of radioactive contamination and confirmed exposure of targets, the investigator recommended this site for an expanded SI.

The number of focused SI sources and environmental samples should be kept to a minimum. Sampling and surveying efforts should focus on investigating target exposure to contamination. The criteria and planning considerations in Table 4-2 apply to sites with radioactive wastes.

Expanded and Single Sl Sampling Principles

Similar to sampling strategies for other hazardous substances, expanded and single SI strategies for radiation sites collect data to:

- Determine site-specific background radioactivity concentrations and exposure rate levels;
- Confirm the identities and activity concentrations of all principal radioactive substances of concern, including decay products;
- Document releases to principle pathways;
- Document Level I and Level II contamination; and
- Support QA/QC requirements.

Table 4-3 applies to expanded SI sampling for radionuclides.

4.9.2 Source Characterization

Evaluations of the hazardous waste quantity factor values for radionuclides differ from the approaches used for other hazardous substances in three primary ways:

- Activity units, rather than mass units, are used to evaluate sources.

- To evaluate radionuclide constituent quantity (Tier A), calculation of the estimated net activity content for the source is based on the activity concentration above the respective background concentration for each radionuclide attributable to the source.

- Only two tiers, Tier A (radionuclide constituent quantity) and Tier B (radionuclide wastestream quantity), are used for determining hazardous waste quantity factor values.

To determine a source hazardous waste quantity factor value based on radionuclide constituent quantity data, the source area and depth (or volume) and the net activity concentration of each radionuclide in the source or area of observed contamination must be obtained.

Surface exposure rate surveys are often used to assess areal extent of observed contamination for the soil exposure pathway. These exposure rates are measured in microroentgens per hour at 1 meter above ground level using hand-held survey meters. Measurements are recorded at grid intersections, and must be accompanied by a set of x- and y- reference coordinates. These measurements should be sufficient to locate maximum gamma exposure rates and indicate zones of equal exposure around these points.

Down-hole gamma logging is performed to estimate depth of contamination. This survey uses gamma sensitive probes lowered into drilled holes to provide measurements of the gamma exposure rate or gamma count-rates at predetermined depth intervals. An expanded SI may require a number of down-hole measurements. Depths of each bore hole should extend to the bottom of the contaminated layers plus at least 1 foot. When grade levels are approximately equal, boreholes should terminate at the same depth.

4.9.3 QA/QC Samples

The types and numbers of QA/QC samples required for focused and expanded SIs at radiation sites are essentially identical to those recommended in Section 4.3 and Table 4-6 for other hazardous substances, with two exceptions. Trip blanks and matrix spike analyses may not be required for radionuclide sampling because of the remote possibility of cross-contamination.

4.9.4 Sample to Demonstrate a Release

The criteria to establish a release by direct observation are pathway-specific and are discussed in each pathway section. The criteria and significance levels to establish an observed release through the analysis of samples for radionuclides differ considerably from the criteria used for other hazardous substances (see HRS Section 7). Radionuclide criteria are divided into three groups:

- Radionuclides that occur naturally or ubiquitous manmade radionuclides in the environment
- Manmade radionuclides that are not ubiquitous in the environment
- External gamma radiation (soil exposure pathway only)

To establish an observed release based on sample analysis for the ground water, surface water, and air pathways for naturally occurring or ubiquitous manmade radionuclides, the measured concentration (in units of activity concentration, such as pCi/g, pCi/L, pCi/M^3) of a given radionuclide in the sample must be at a level that:

- Equals or exceeds a value of two standard deviations above the mean site-specific background concentration for that radionuclide in that type of sample; or

- Exceeds the upper-limit value of the range of regional background concentration values for that specific radionuclide in that type of sample.

In both cases, some portion of the increase must be attributable to the site to establish an observed release.

To establish areas of observed contamination for the soil exposure pathway, the measured concentration of naturally occurring or ubiquitous manmade radionuclides in soil samples (in activity units) must meet the above criteria, and the radionuclide must be present at the surface or covered by 2 feet or less of cover material.

To establish an observed release for manmade radionuclides without ubiquitous background concentrations in the environment, the following criteria must be met:

- The measured activity concentration of a given radionuclide in the sample must equal or exceed the SQL for that radionuclide in that specific medium.

- The increase in the sample activity concentration for that radionuclide in a specific medium must be attributable to the site.

Under special circumstances, the following sets of criteria may apply. If the radionuclide concentration equals or exceeds the SQL, but its release can be attributed to one or more sites, the measured concentration of that radionuclide in the sample must also:

- Equal or exceed a value of two standard deviations above the mean concentration of that radionuclide contributed by those neighboring sites; or

- Equal three times its background concentration, whichever is lower.

To establish observed contamination for the soil exposure pathway, the measured concentration of a nonubiquitous manmade radionuclide in soil samples must meet the criteria listed above, and the radionuclide also must be present at the surface or covered by 2 feet or less of cover material.

For the soil exposure pathway, observed contamination is also established if the gamma radiation exposure rate equals or exceeds a level equal to twice the site-specific background gamma radiation exposure rate. Some portion of the increase in the gamma radiation exposure rate must be attributable to the site. If gamma-emitting radionuclides can be detected where persons may be exposed to gamma radiation, the radionuclides do not have to be present at the surface or covered by 2 feet or less of cover material to establish observed contamination.

Level I and Level Il actual contamination of targets evaluation uses different media-specific benchmarks for radioactive substances (see HRS Section 7). For the soil exposure pathway, Level I concentrations are assigned automatically to a sampling location if the external gamma radiation exposure rate (in units of μR/hr measured with a survey instrument at 1 meter above the ground surface) equals or exceeds two times the background level.

4.9.5 Ground Water and Surface Water Pathways

In addition to the guidance provided in Sections 4.5 and 4.6, the SI investigator should be aware of special considerations for collecting and analyzing ground water and surface water aqueous samples and surface water sediment and tissue samples for radioactive substances. The SI investigator should check with EPA Regional, laboratory, or Headquarters Radiation Programs staff for guidance and standard procedures manuals (U.S. EPA, 1984, and U.S. DOE, 1983) and special instructions regarding sample collection, handling, and preservation.

With the exception of tritium, water samples for radionuclides should be collected in clean plastic or teflon containers. Tritium samples should be collected in glass containers only. The standard preservation technique for radionuclides in water is acidification to a pH of less than 2 using nitric or hydrochloric acid. Preservatives should be added as soon as possible after filtration. The following are exceptions:

- Tritium, C-14, and isotopes of iodine should not be acidified and analysis should be conducted as soon as possible after collection.
- Cesium radioisotopes should be preserved with hydrochloric acid only.

In all cases, the laboratory performing the radioanalysis should be contacted prior to sample collection for their recommendations on sample handling and preservation.

The volume of water sampled can range from a few milliliters to several liters, depending on the decay mode, radiation abundance and half-life of the radionuclide, expected concentrations, and the sensitivity of the radioanalytical method. The laboratory should be consulted for recommendations. Holding times for water samples depend primarily on the half-life of the radionuclide. Again, the analytical laboratory should be consulted on this issue. Radionuclide water concentrations are reported in activity concentration units, usually in picocuries per liter (pCi/L).

Like SIs for non-radioactive waste investigations, radioactive sediment samples are taken to establish a release to surface water and to document targets exposed to actual contamination. If surface water sediment and aqueous samples are co-located, the sediment samples should be collected after the aqueous samples. In some cases where high levels of gamma-emitting radionuclides have been released, submersible radiation detection survey probes and instruments may aid in the selection of sediment sample locations.

Handling and preservation techniques for surface water sediment samples are similar to those for soil samples. Core sediment samples are usually frozen in the collection tubes, sectioned (1 to 6 inches in length depending on analytical sensitivity), air- or oven-dried, ground, and analyzed either intact or after radiochemical separation and concentration.

For surface water tissue sampling and analysis, two key factors should be considered: the species of aquatic organism sampled; and the portion of the organism analyzed. Radionuclide concentrations in aquatic organisms can vary among different species based on feeding habits, habitat, and position in the food chain. Certain radionuclides may also concentrate in specific tissues. For example:

- Strontium-90, cesium-137, manganese-54, and radium tend to concentrate in the shells of freshwater crustaceans and mollusks.
- Cobalt-60 accumulates in the kidney.
- Iron-55 and iron-59 accumulate in the spleen and kidney.
- Zinc-65 accumulates in the spleen and liver.

Tissue sampling locations and methods for radionuclides are similar to those described in Section 4.6. Tissue samples are normally frozen before analysis. Special care should be taken when wet- or dry-ashing biological samples containing polonium, cesium, lead, manganese, or cobalt are being analyzed to avoid volatilization of these radionuclides. Tissues containing radionuclides should not be dry-ashed or treated with oxidizing agents. If tissue sample analysis is necessary to evaluate actual contamination of a fishery, replicate samples may be needed due to the uncertainty of the exposure history of these organisms.

Concentrations of radionuclides in surface water sediment and tissue samples are generally reported in activity concentration units of picocuries per gram (pCi/g) or per kilogram (pCi/kg) on a wet weight basis.

4.9.6 Soil Exposure Pathway

In addition to the guidance provided in Section 4.7, the SI investigator should be aware of special considerations for collecting and analyzing soil for radioactive substances.

In general, no preservation techniques are required for radionuclide soil samples. However, soil samples with high organic levels should be dried or ashed, with the following exceptions:

- Aliquots of soil samples selected for H-3 should not be dried or ashed.
- Aliquots of soil samples selected for C-14 should not be ashed or leached with acid.
- Aliquots of soil samples selected for elements with volatile oxidized forms (e.g., I, Tc) should not be treated with oxidizing acids.
- Aliquots of soil samples selected for Ra-226 analysis by gamma spectrometry should be dried, crushed, or sieved, but an appropriate post-preparation holding time is necessary to reach equilibrium with radon daughters.

Holding times for soil samples depend primarily on the half-lives of the radionuclides to be analyzed. Soil sample amount depends on a number of factors, including (but not limited to) the decay modes, halflives and expected concentrations of the specific radionuclides, analytical sensitivity, and analysis time. Concentrations of radionuclides in soil are generally reported in activity concentration units of picocuries per gram (pCi/g) of dry soil.

4.9.7 Air Pathway

In addition to the guidance provided in Section 4.8, the SI investigator should be aware of special considerations for collecting and analyzing air samples for radioactive substances.

In general, suspended radioactive particulates should be collected on a filter using a high-volume sampler

at high flow rates (> 20 ft^3/min). For radiochemical analysis, membrane filter paper are preferred because they are readily ashed. Either membrane filters or glass fiber filters are suitable for direct counting of activity on the filter. Collection efficiencies for both types of filters remain high (> 99 percent) over a wide range of particle sizes and filtration velocities, however both produce moderately high pressure drops and are fragile. Radioactive air samples are usually collected over a period of several hours to days. The laboratory performing the analyses should be consulted for recommended sampling procedures and times prior to collection. Filter sample measurements should be delayed for at least 5 hours after collection to allow for the decay of short-lived radon progeny that are also collected on the filter from ambient air. Gaseous isotopes of iodine (primarily I-131) should be collected on an activated charcoal cartridge or on silver zeolite. Particulate iodine should be collected on a glass fiber or membrane filter. Normally, both gaseous and particulate iodine are collected simultaneously in a sampling apparatus consisting of a particulate filter, charcoal cartridge, and vacuum pump in series.

Tritium, in the form of vitiated water vapor, is usually collected from the atmosphere onto silica gel (see NCRP, *Tritium Measurement Techniques*, NCRP Report No. 47, (1976)). Tritium vapor should be sampled at high flow rates for a few days to collect larger sample volumes and increase detection sensitivity. However, care must be taken to control the flow rate and sampling time to avoid oversaturation of the gel with water vapor. Temperature and humidity are important factors to consider in determining sampling times and flow rate. Air sample volumes for radionuclide analyses normally range from 1 to 30 or more cubic meters. Concentrations of radionuclides in air samples are usually reported in units of picocuries per liter of air (pCi/L) or in units of picocuries per cubic meter of air (pCi/ni).

4.10 SUMMARY

SI objectives determine the types, number, and location of samples to collect. By evaluating the benefits of sampling at specific locations and assessing the validity of analytical data available before sampling, the investigator will be able to achieve the dual goals of meeting SI objectives and conserving Superfund resources. Because the SI is a limited-scope, biased sampling event, strategic selection of sample locations is perhaps the most critical decision that will affect the success of the investigation. Table 4-18 summarizes the focused and expanded SI strategies designed to optimize selection of sample locations.

TABLE 4-18: SUMMARY OF SI SAMPLING STRATEGY

FACTOR	PA STRATEGY	FOCUSED SI STRATEGY	EXPANDED AND SINGLE SI STRATEGY
Hazardous substance characteristics	Maximum values assumed[1]	Sample sources to identify specific hazardous substances present at the site.	Same
Hazardous waste quantity	Calculated value	Review PA data; obtain additional records; obtain source quantity and area measurements; do not sample to determine hazardous waste quantity; contaminated soil source area may be estimated based on visual observations.	Review previous data; in limited cases, sample to determine hazardous waste quantity; contaminated soil source area may be further characterized based on analytical data.
Release to ground water	Suspected release	Sample nearest well suspected to be exposed to hazardous substances. Sampling to test a suspected release could be conducted in conjunction with sampling to test contaminated target hypothesis.	Sample wells likely to be exposed to hazardous substances. Sampling to document a release could be conducted in conjunction with sampling to document targets exposed to actual contamination. Install and sample monitoring wells if ground water pathway is significant to scoring and attribution is an issue. If necessary, resample focused SI locations.
Drinking water targets exposed to actual ground water contamination	Primary targets	Sample nearest drinking-water wells suspected to be contaminated. Sample municipal wells, regardless of depth, if reasonable probability of site related contamination.	Sample drinking-water wells likely to be contaminated. Sample municipal wells, regardless of depth, if there is some reasonable probability of site related contamination. If necessary, resample focused SI locations. Note that for metal analysis, filtering may be necessary.
Release to surface water	Suspected release	Sample at or just downstream of the probable point of entry. Sampling to test a suspected release could be conducted in conjunction with sampling to test a contaminated target hypothesis. Also consider direct observation option.	Sample at or just downstream of the probable point of entry. Sampling to document a release could be conducted in conjunction with sampling to document targets exposed to actual contamination. If necessary, resample focused SI locations. Also consider direct observation option.

TABLE 4-18: SUMMARY OF SI SAMPLING STRATEGY (CONTINUED)

FACTOR	PA STRATEGY	FOCUSED SI STRATEGY	EXPANDED AND SINGLE SI STRATEGY
Drinking water targets exposed to actual surface water contamination	Primary targets	Collect sediment and aqueous samples at or beyond the pont of drinking water withdrawal prior to treatment. Note that Level I contamination can only be scored based on aqueous sample results.	Collect sediment, aqueous, and benthic samples at or beyond points of drinking water withdrawal prior to treatment. If necessary, resample focused SI locations. Note that Level I contamination can only be scored based on aqueous samples. Note that for metal analysis, filtering may be necessary.
Human food chain organisms exposed to actual surface water contamination	Primary targets	Collect sediment and aqueous samples from within or beyond the fishery boundary and as close to the PPE as possible. Tissue samples should generally not be collected at the focused SI.	Collect sediment, aqueous, and benthic tissue samples from within or beyond the fishery boundary. Collect other tissue samples (e.g., fish) from within or beyond the boundaries of actual fishery contamination. If necessary, resample focused SI locations. Note that Level I contamination can only be score based on tissue samples. Only collect tissue samples if human food chain threat is significant to scoring.
Sensitive environments exposed to actual surface water contamination	Primary targets	Collect sediment and aqueous samples at or beyond the sensitive environment. Sampling to test suspected contamination of a surface water sensitive environment may be conducted in conjunction with sampling to test a suspected release to surface water. If possible, collect at least two samples 0.1 miles apart to test suspected contamination of a wetland. Note that Level I contamination can only be scored based on aqueous sample results.	Collect sediment and aqueous samples at or beyond the sensitive environment. Sampling to document a release to surface water may be conducted in conjunction with sampling to document targets exposed to actual contamination. If possible, collect at least two samples 0.1 miles apart to document contamination of a wetland. Note that Level I contamination can only be scored based on aqueous sample results.

TABLE 4-18: SUMMARY OF SI SAMPLING STRATEGY (CONCLUDED)

FACTOR	PA STATEGY	FOCUSED SI STRATEGY	EXPANDED AND SINGLE SI STRATEGY
Observed surficial contamination	Surficial contamination assumed[1]	Sample source areas to determine surficial contamination. Sampling for this factor should be conducted in conjunction with waste and source characterization samples. Samples must be collected from a depth of 2 feet or less.	Sample source areas to better characterize observed surficial contamination. Sampling for this factor should be conducted in conjunction with source characterization. Samples must be collected from a depth of 2 feet or less.
Resident population targets exposed to ob served surficial contamination	Resident population	Sample properties suspected of being resident targets. Samples must be collected from within the property boundary and 200 feet from targets, except for terrestrial sensitive environments for which samples must be collected from within environment boundaries.	Sample properties suspected of being resident targets. Samples must be collected from within the property boundary and 200 feet from targets, except for terrestrial sensitive environments and resources, for which samples must be collected from within the environment or resources boundaries.
Release to air	Suspected release	Sampling to test a suspected release to air when only the air pathway is cause for further investigation. Generally, air sampling is an expanded SI activity.	Sample to document a release when this pathway is the only significant pathway to scoring. Some sample locations should be located away from site sources.
Populations and sensitive environments exposed to actual air contamination	Primary targets	Evaluate targets based on their location relative to the distance category in which the release to air is evaluated.	Evaluate targets based on their location relative to the distance category in which a release to air is documented.

[1]Unless analytical data indicate otherwise